Evaluation of Striped Bass Stocks in Virginia: Monitoring and Tagging Studies, 2004-2008

Annual Report

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Figure 1. Locations of the commercial pound nets and experimental gill nets sampled in spring spawning stock assessments of striped bass in the Rappahannock River, 1991-2005.

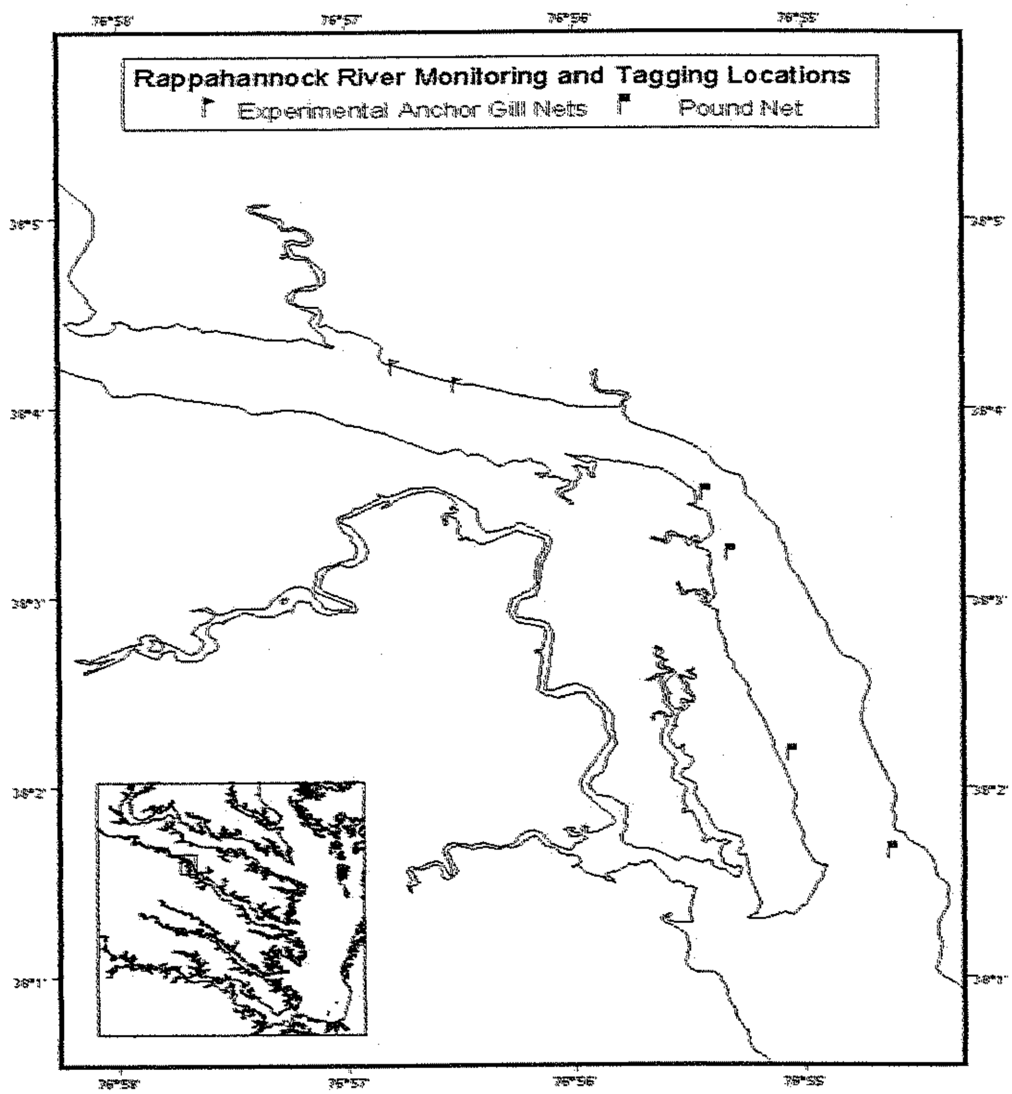


Figure 2. Locations of the experimental anchor gill nets sampled in spring spawning stock assessments of striped bass in the James River, springs 2003-2005.

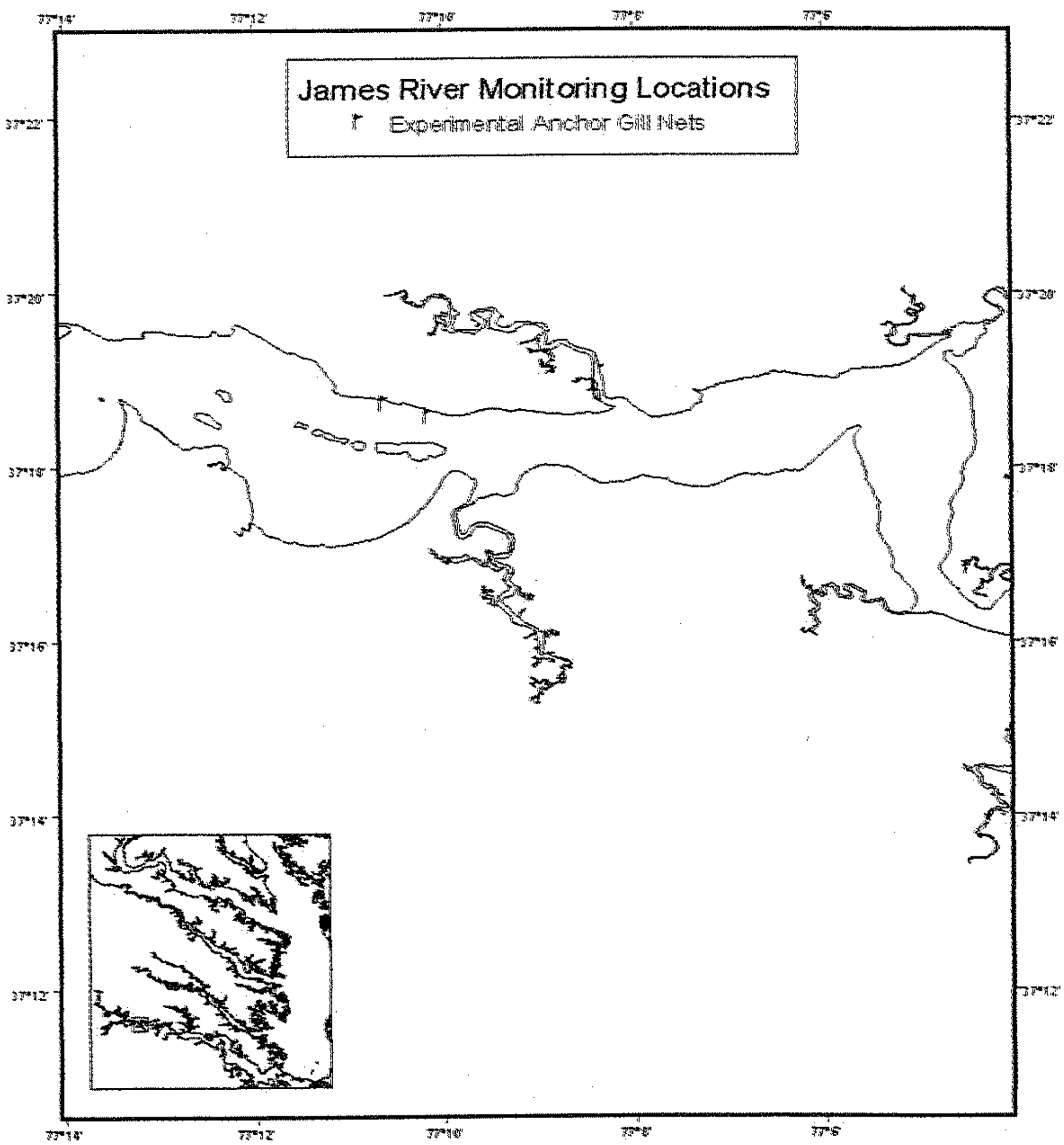


Figure 3. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1987 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

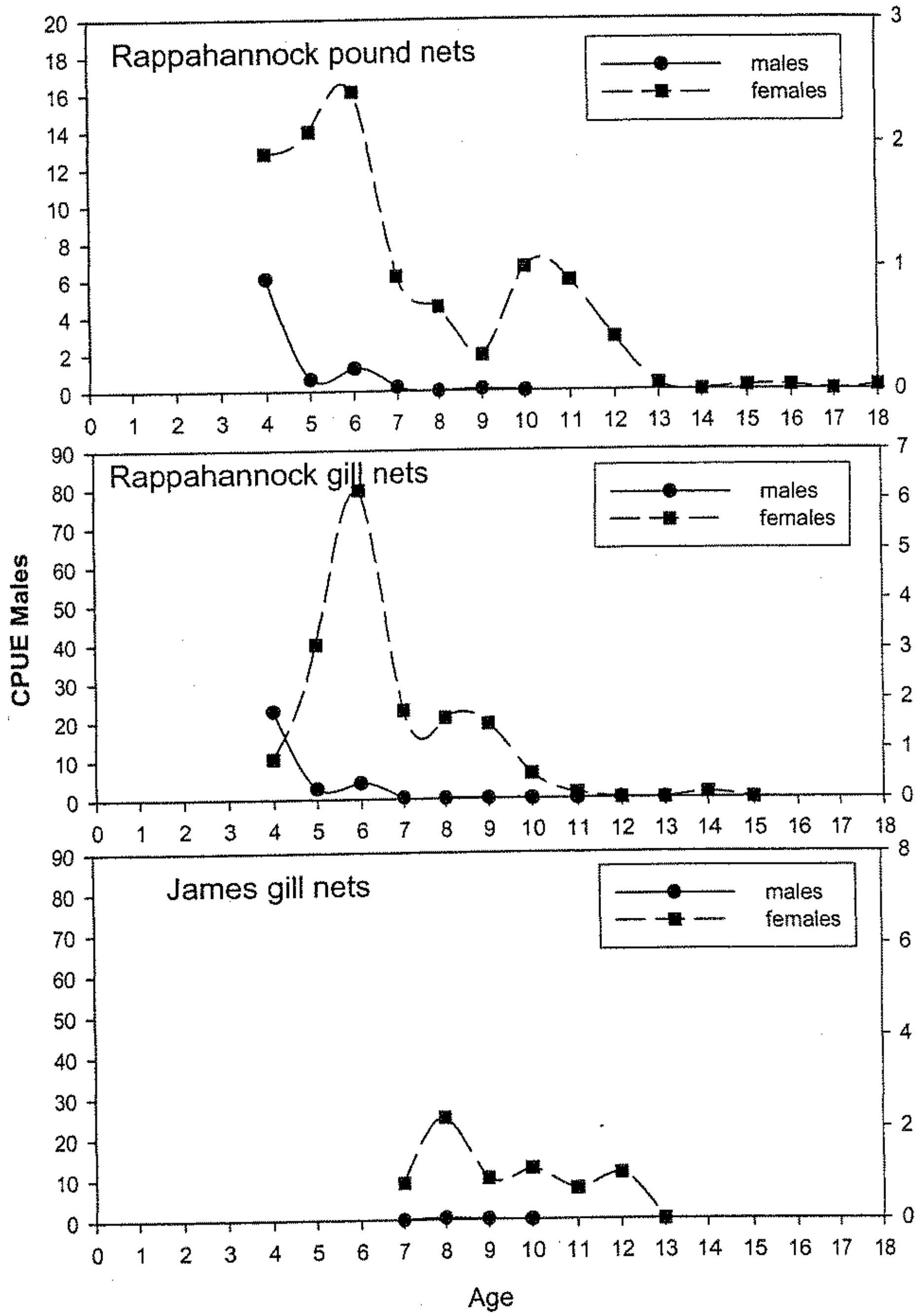


Figure 4. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1988 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

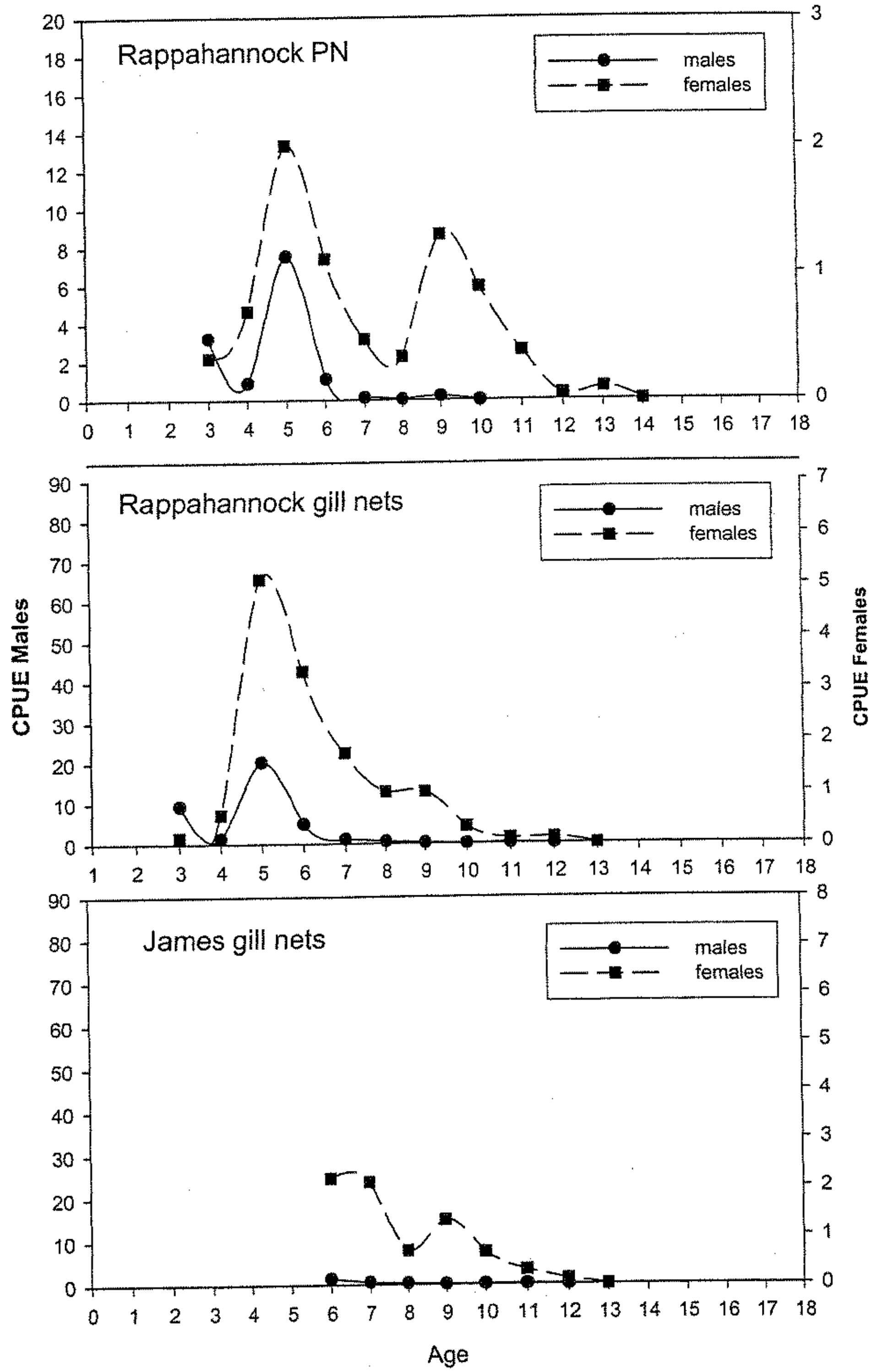


Figure 5. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1989 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

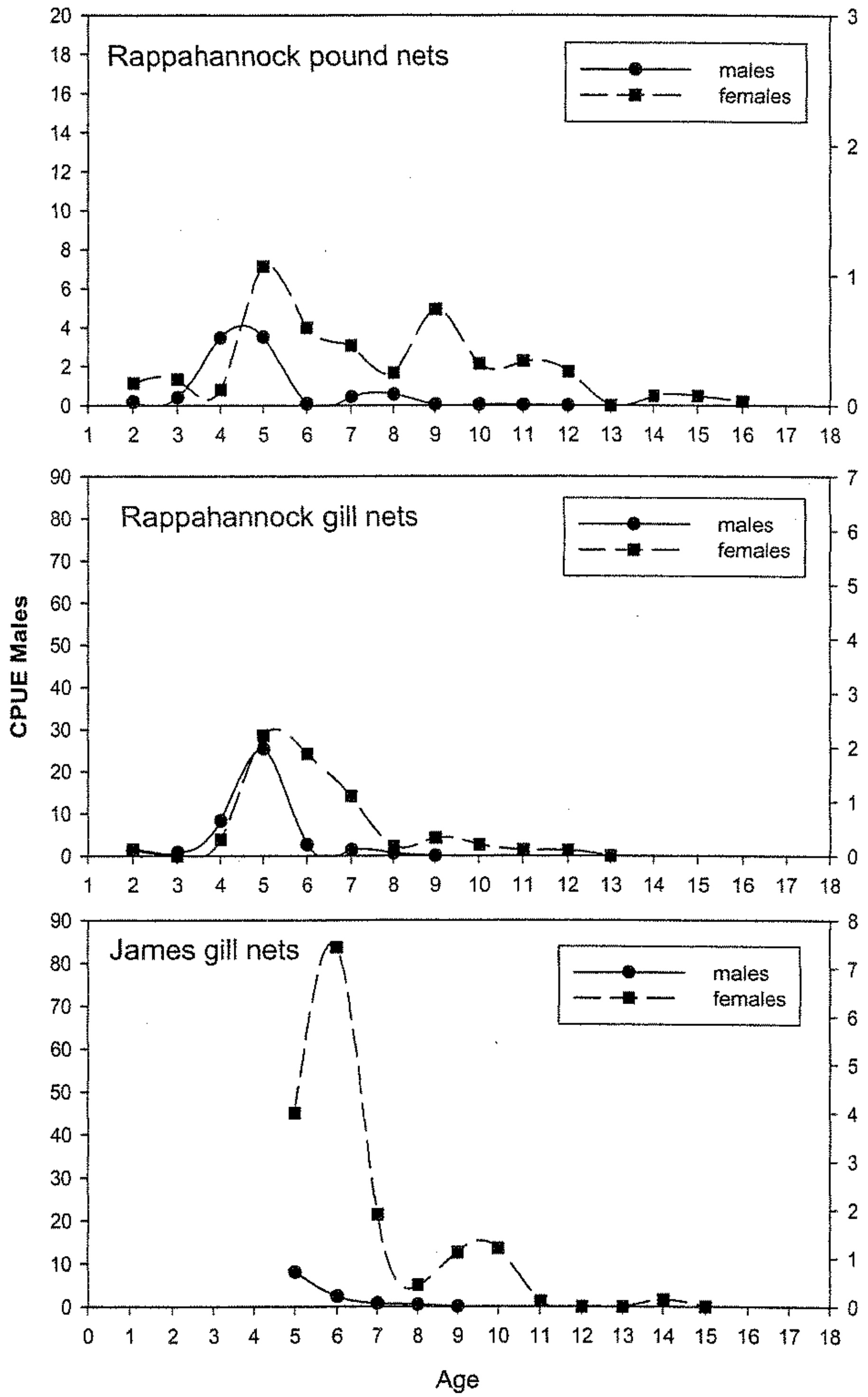
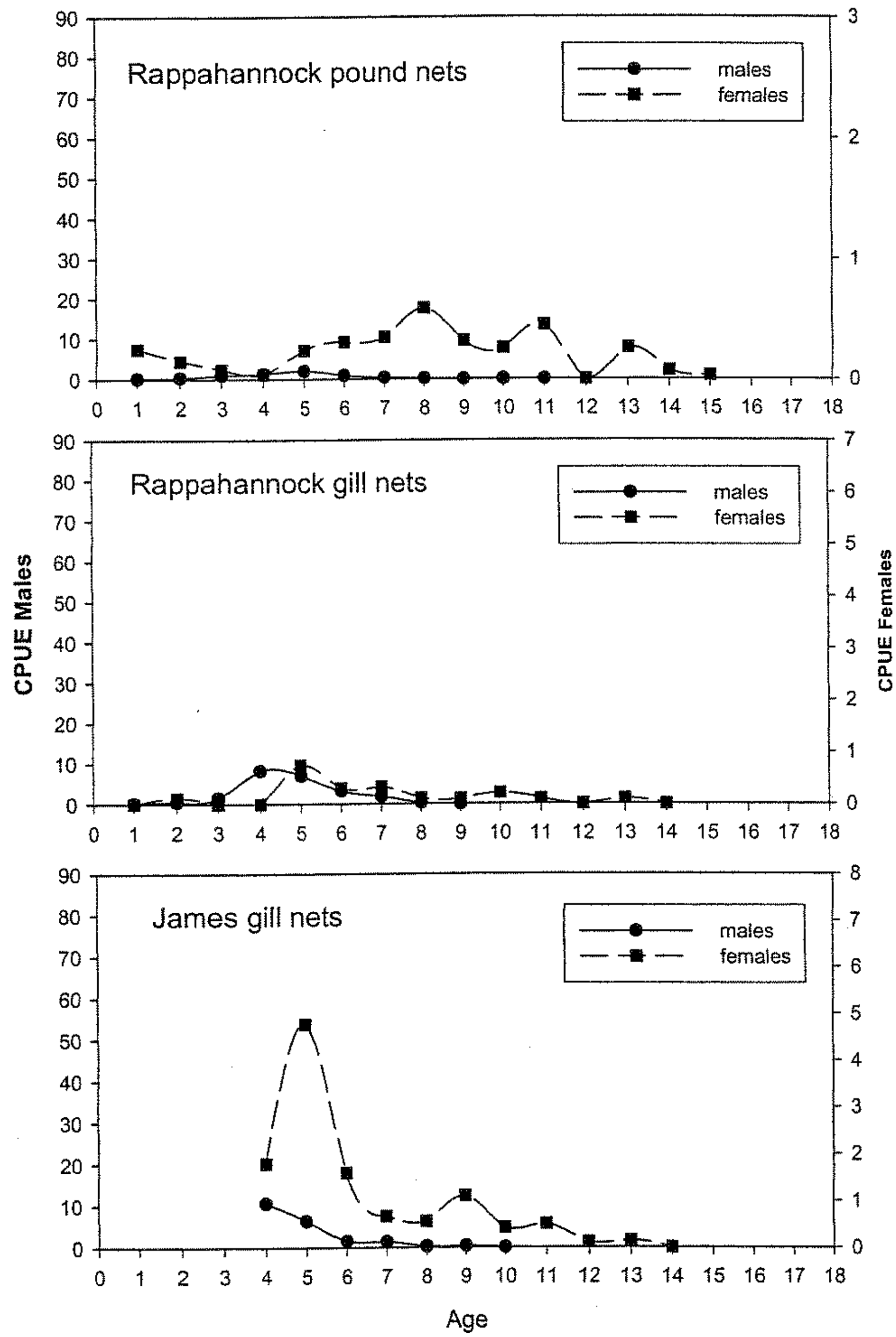


Figure 6. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1990 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.



lower river flows than had been present in 2001-2003. Catches of female striped bass peaked on 21 April, but were generally high from 21-28 April. Males made up 72.1% of the total catch, but this was slightly below the 15-year average (77.2%). The 2001-2003 year classes comprised 41.5% of the total catch. Males dominated the 2001-2003 year classes (99.6%) and the 1997-2000 year classes (78.9%), but females dominated the 1987-1996 year classes (85.8%).

Biomass catch rates (g/day) of male striped bass peaked on 31 March and female striped bass were highest on 21 April (Table 2). The numeric catch rate of females exceeded that of males only on 21 April. However, the biomass catch rates for female striped bass exceeded that for males overall (1.47:1), peaking on 21 April (4.33:1). The mean ages of male striped bass varied from 3.7-5.8 years by sampling date, with the oldest mean ages occurring from 25-28 April. The mean ages of females varied from 9.0-10.6 years by sampling date, but only varied from 9.4-9.8 years from 18 April – 2 May.

There was a peak in abundance of striped bass (mostly male) between 450-500 mm total length in the pound net samples (Table 3). This size range accounted for 21.1% of the total sampled. There was a secondary peak in abundance of striped bass between 810-860 mm total length, accounting for 11.7% of the total sampled. However, the striped bass from 630-740 mm total length accounted for only 3.4% of the total sample. The total contribution of striped bass greater than 710 mm total length (the minimum total length for the coastal fishery) was 36.8%.

During the 30 March - 3 May period, the 2001 (30.8%) and 2000 (15.7%) year classes were the most abundant (Table 4). These year classes were 96.2% male. The contribution of males age six and older (the pre-2000 year classes) was 15.9% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was 26.6% of the total aged catch, but was also 92.7% of the total females captured. The catch rate (fish/day) of male striped bass was 12.7, which is 16.4% below the 13-year average (Table 5). The catch rate of female striped bass (4.9 fish/day) was 11.4% above the 13-year average, but was less than in 2003 or 2004. The biomass catch rates (kg/day) of both sexes were above the average of the 13-year time series. The mean ages (30 March – 3 May) of both sexes were above the 13-year averages.

Experimental gill nets: Striped bass (n= 322) were also sampled between 30 March and 3 May, 2005 from two multi-mesh experimental gill nets in the Rappahannock River. The total catch was 61.1% less than in 2004. Total catches peaked on 18 and 21 April, due to the large number of three to six year old males (Table 6). Female striped bass were generally caught in low numbers throughout the sampling period. Males made up 91.6% of the total catch. Males dominated the 2001-2003 year classes (100%) and the 1997-2000 year classes (93.8%), but the 1987-1996 year classes were 67.9% female

Biomass catch rates (g/day) of male striped bass were highest on 21 April (Table 7). The catch rates of female striped bass were highest on 18 and 25 April. The catch rate of males exceeded that of females on every sampling occasion. The mean ages of male striped bass varied from 4.3-5.9 years by sampling date (excluding the one male captured on 2 May), with the oldest males (five - nine years) being most abundant from 25-28 April. The mean ages of females varied from 8.0-11.0 years by sampling date, with the oldest females (age nine and older) being most abundant from 14-25 April.

There was a peak in the distribution of length frequencies of striped bass in the gill net samples between 440-550 mm TL (Table 8). In previous years, there was a distinct secondary peak of larger striped bass, but this was less apparent in 2005. In contrast to the pound net samples, the total contribution of striped bass greater than 850 mm total length was 5.9% vs. 20.3% in the pound nets. The total contribution of striped bass greater than 710 mm total length was 14.9% in the gill nets.

During the 30 March - 3 May period, the 2001 (36.6%) and 2000 (20.5%) year classes were most abundant (Table 9). These year classes were 99.5% male. The contribution of males age six and older (the pre-2000 year classes) was 20.1% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was 7.5% of the total aged catch but was 88.9% of the total females captured. The catch rate (fish/day) of male striped bass was the third lowest in the 13-year time series and was 41.0% below the average (Table 10). The catch rate of female striped bass was also the third lowest in the time series and was 54.2% below the 13-year average. The biomass catch rates (g/day) for both sexes were also among the lowest in the time series.

James River:

Experimental gill nets: Striped bass (n= 820) were sampled between 30 March and 3 May, 2005, from two multi-mesh experimental gill nets at mile 62 in the James River. Total catches peaked first on 31 March and again on 2 May. Young, male striped bass were primarily responsible for the peak catches (Table 11). Catches of female striped bass were consistent, although small. Males dominated the 2001-2003 year classes (99.5%) and the 1997-2000 year classes (96.1%), but the 1987-1996 year classes were nearly equal by sex (53.1% male).

Biomass catch rates (g/day) of male striped bass peaked strongly on 7 April and on 2 May, but were high throughout the sampling season (Table 12). The catch rates of female striped bass were highest on 21 April. The biomass catch rate of males exceeded that of females on every sampling date (6.9:1 for the season). The mean ages of male striped bass varied from 4.3-5.2 years by sampling date. The mean ages of females varied from 6.0-11.3 years by sampling date, but varied from only 8.0-11.3 years from 31 March -21 April.

There was a broad peak of striped bass 430- 640 mm total length in the gill net length frequencies (Table 13). This size range accounted for 71.0% of the striped bass sampled. In contrast to the samples from the pound nets (19.9%) from the Rappahannock River, striped bass greater than 850 mm total length accounted for only 3.8% of the total sampled. The total contribution of striped bass greater than 710 mm total length was 11.8%.

During the 30 March - 3 May period, the 2001 (45.4%), 2000 (24.3%) and 2002 (17.9%) year classes were the most abundant in the gill nets (Table 14). These year classes were 99.2%

Figure 7. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1991 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

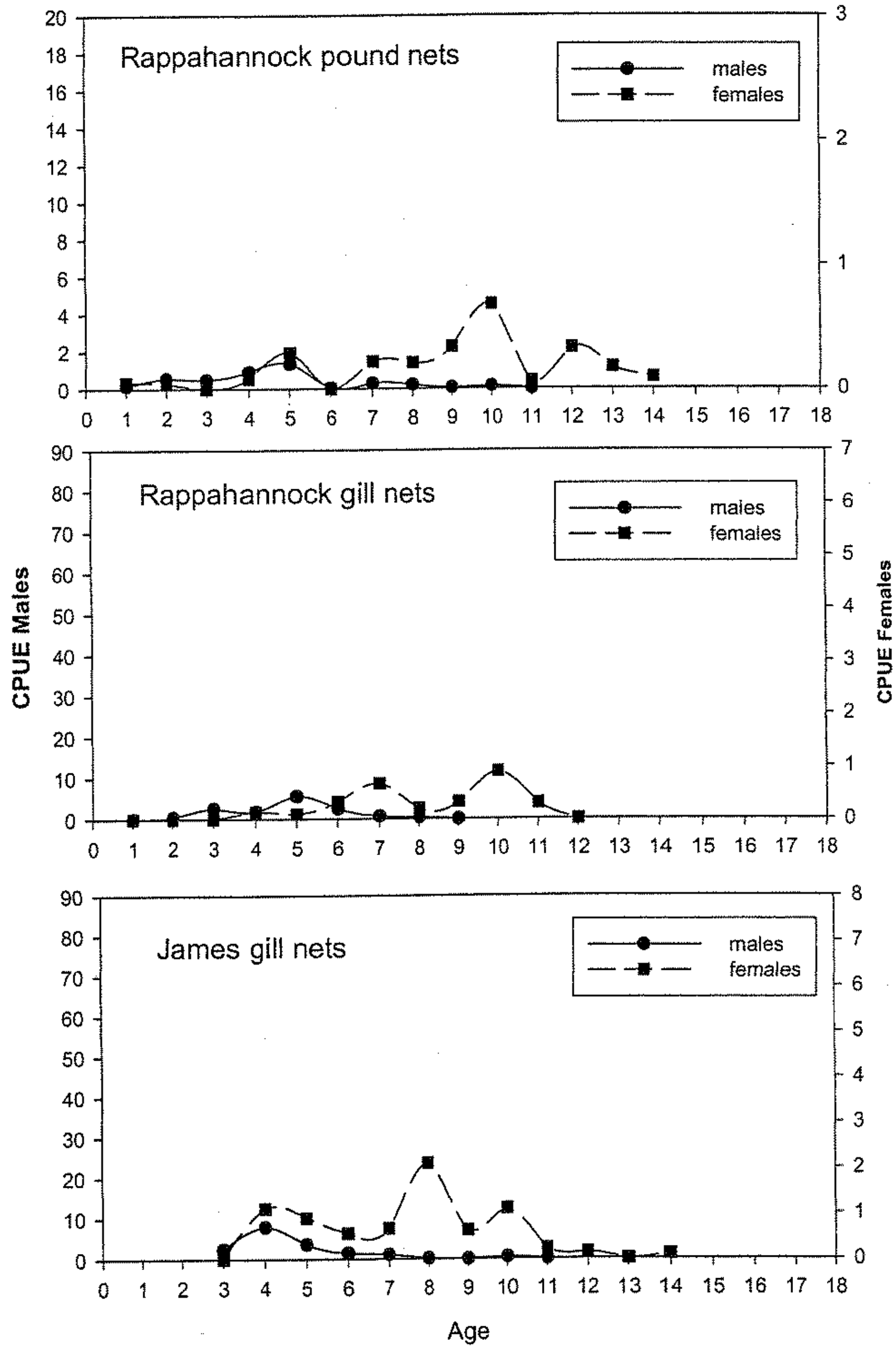


Figure 8. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1992 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

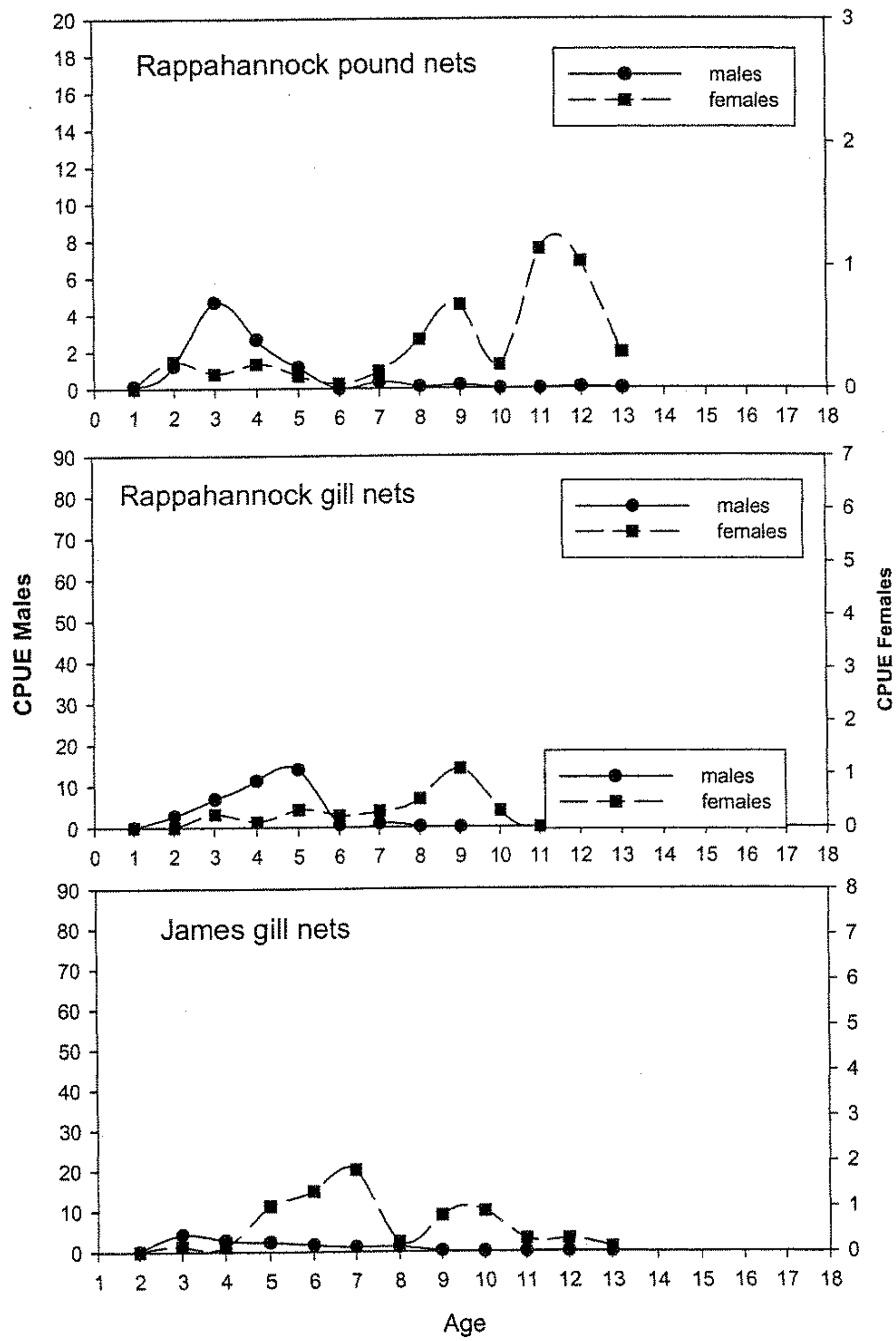


Figure 9. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1993 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

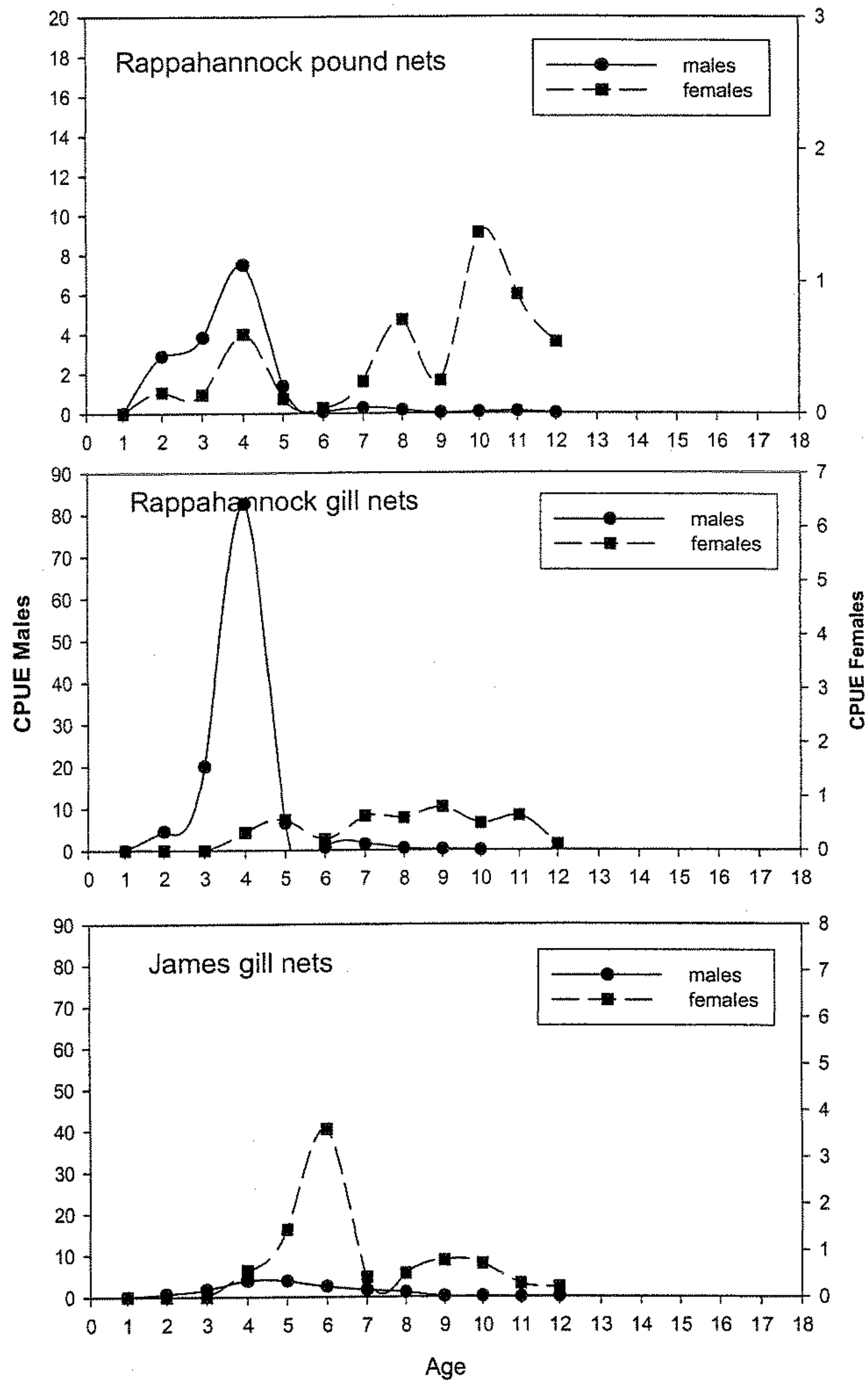


Figure 10. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1994 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

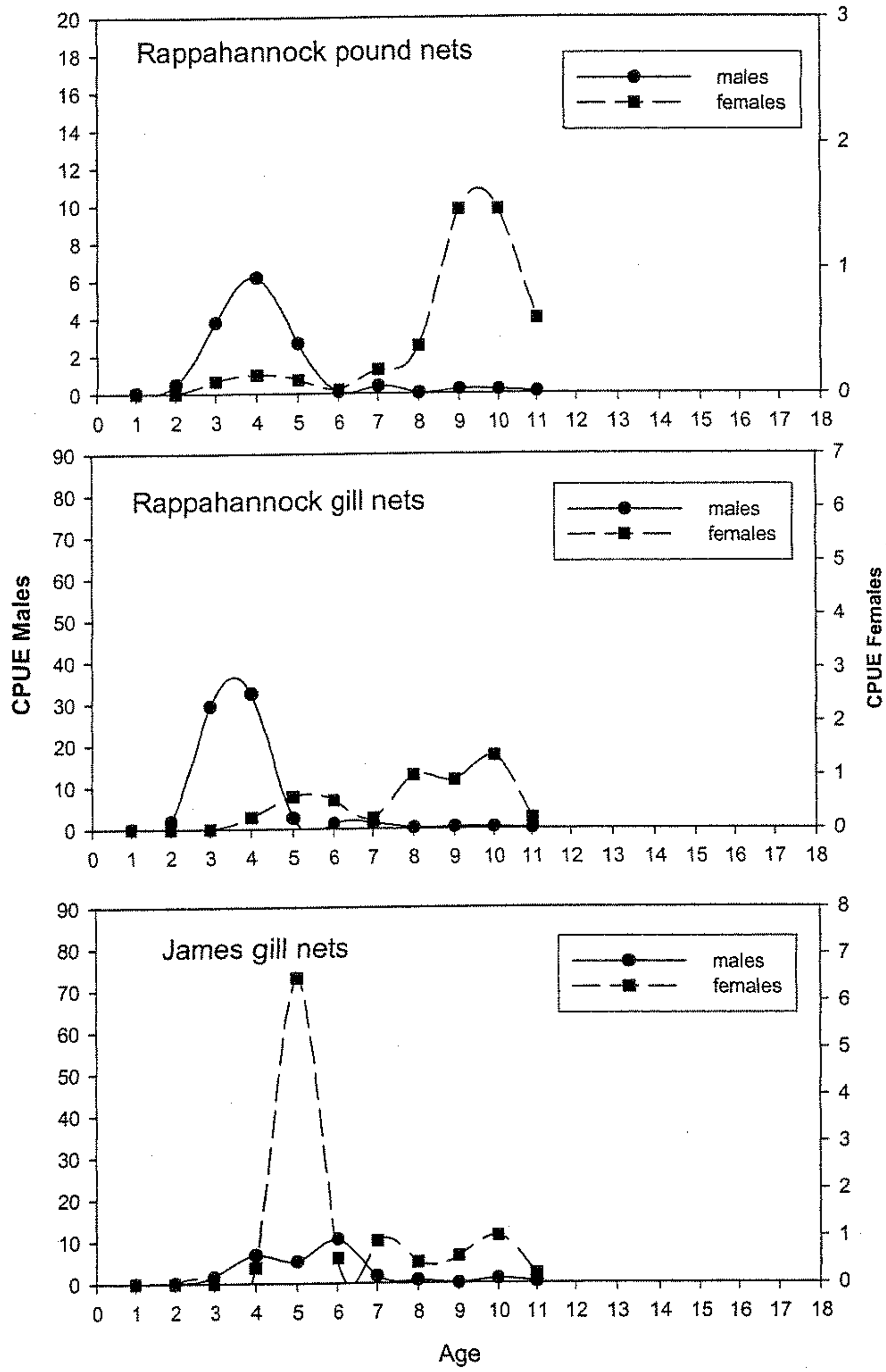


Figure 11. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1995 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

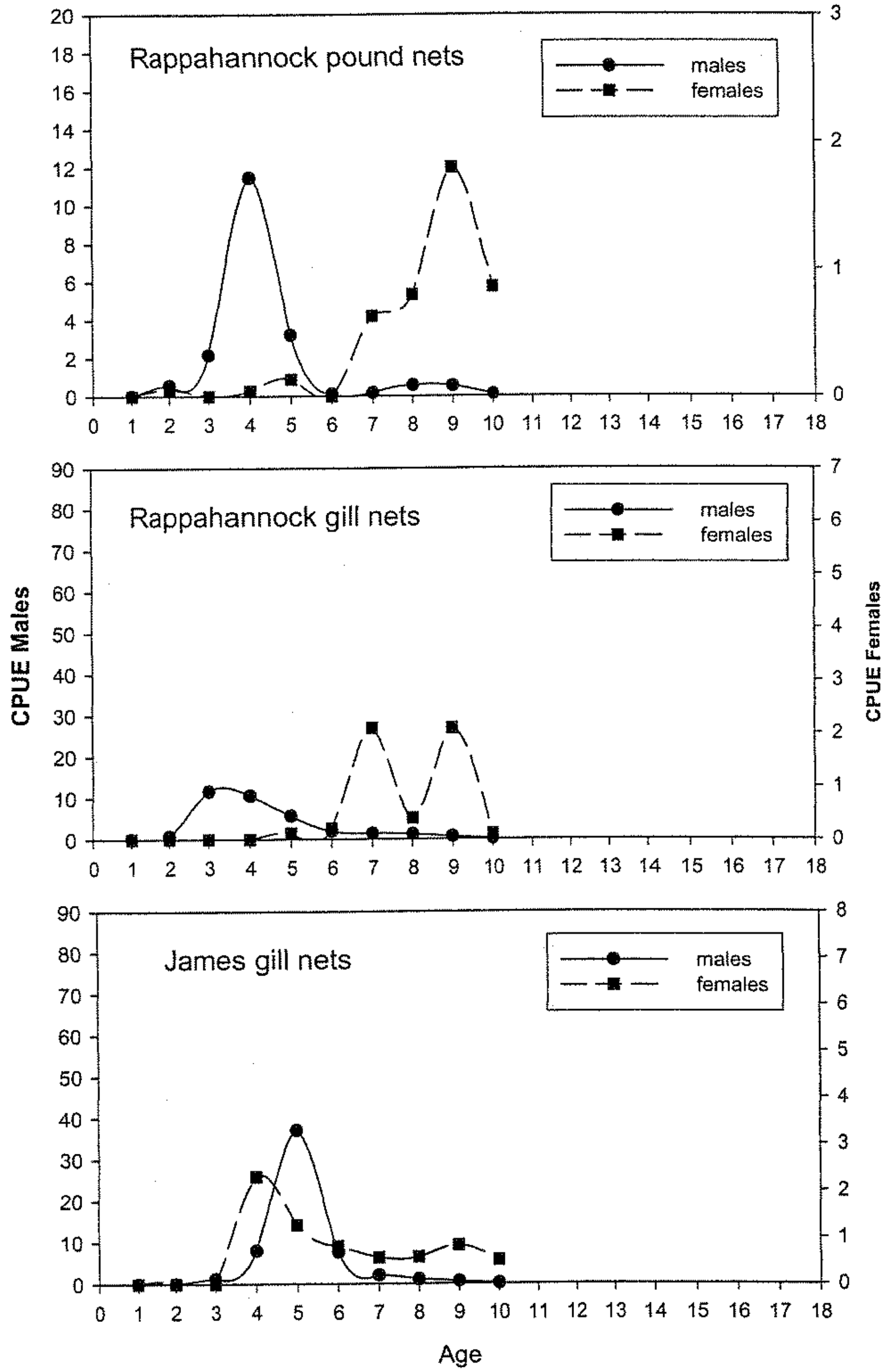


Figure 12. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1996 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

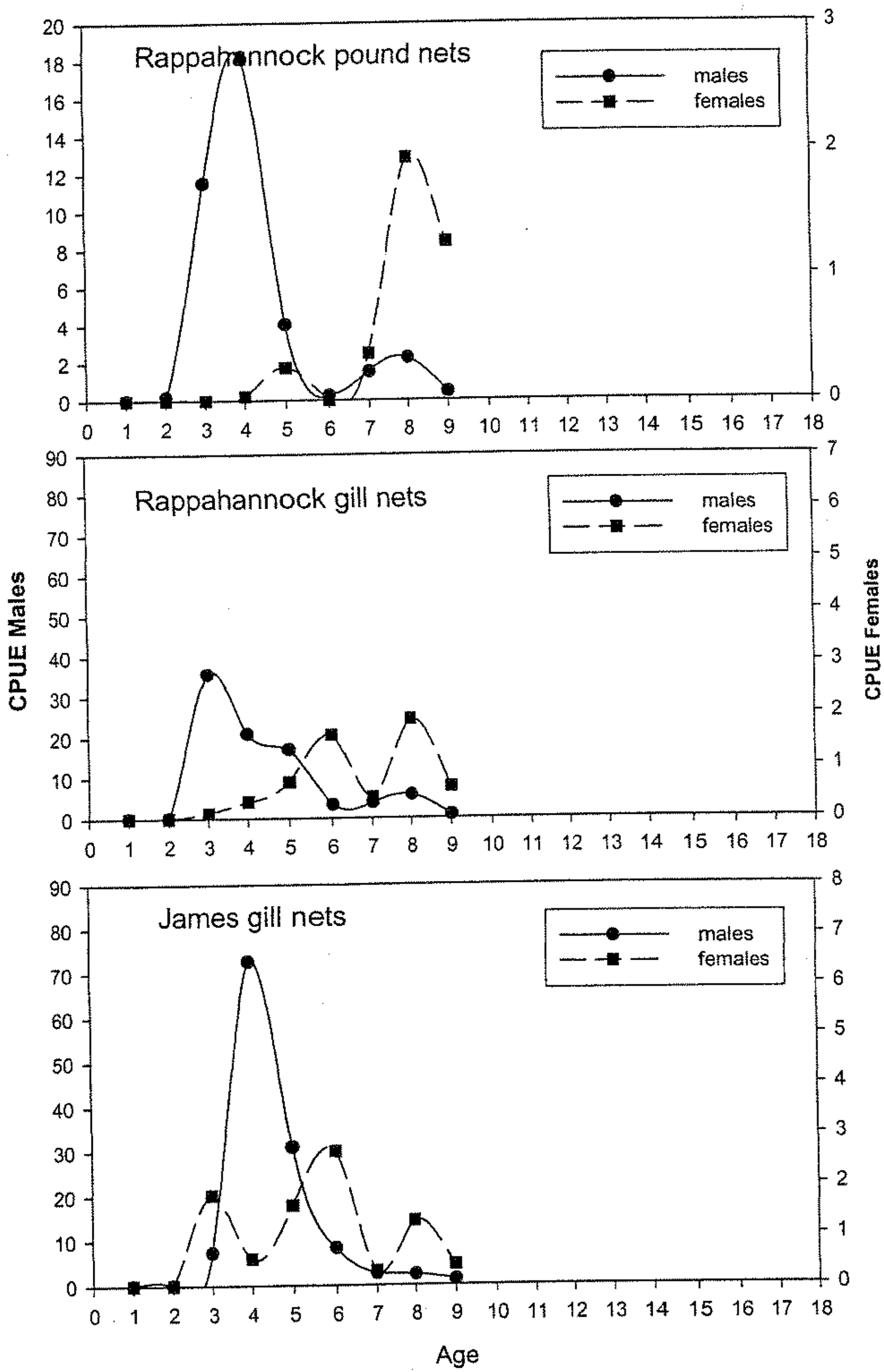


Figure 13. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1997 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

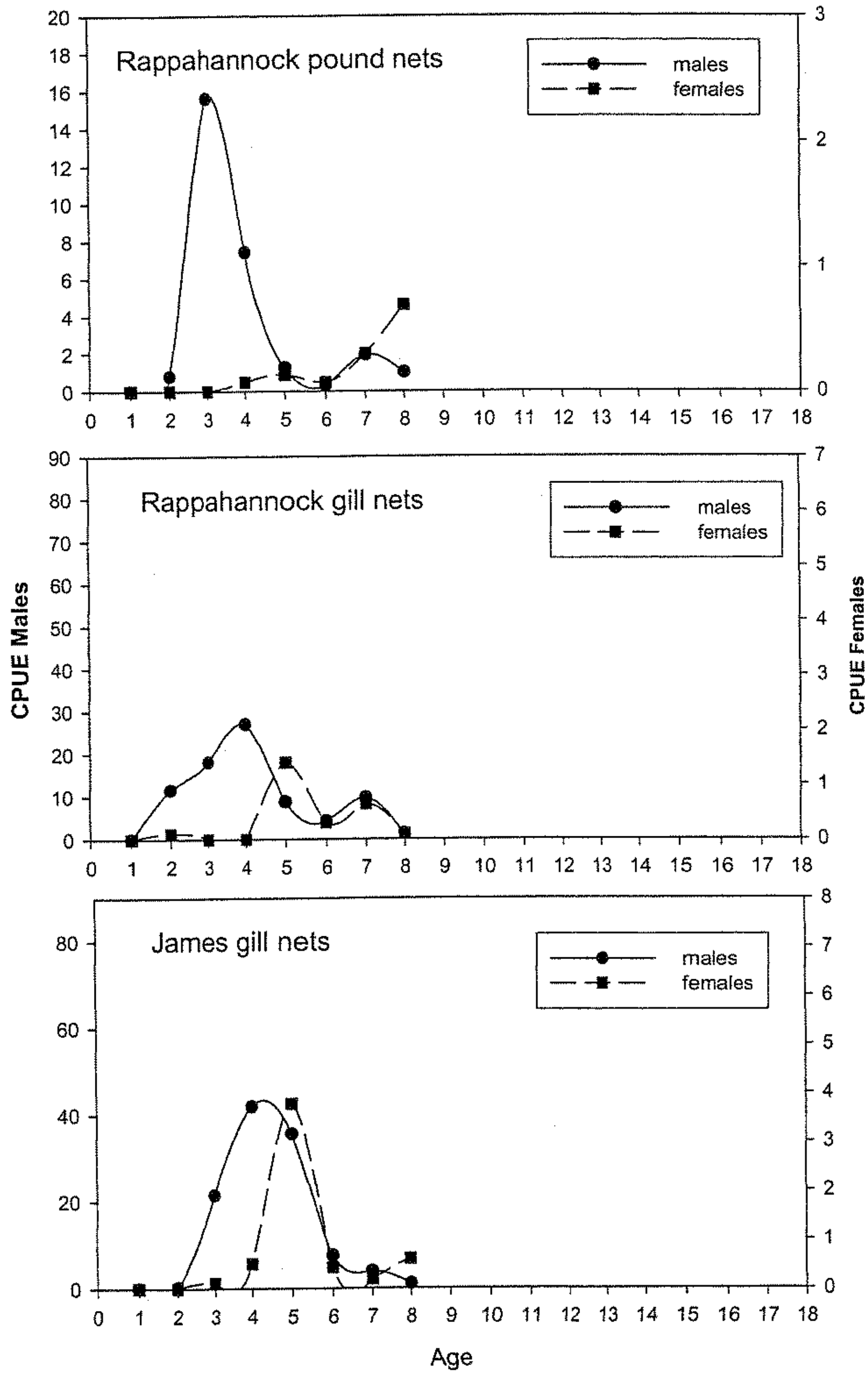
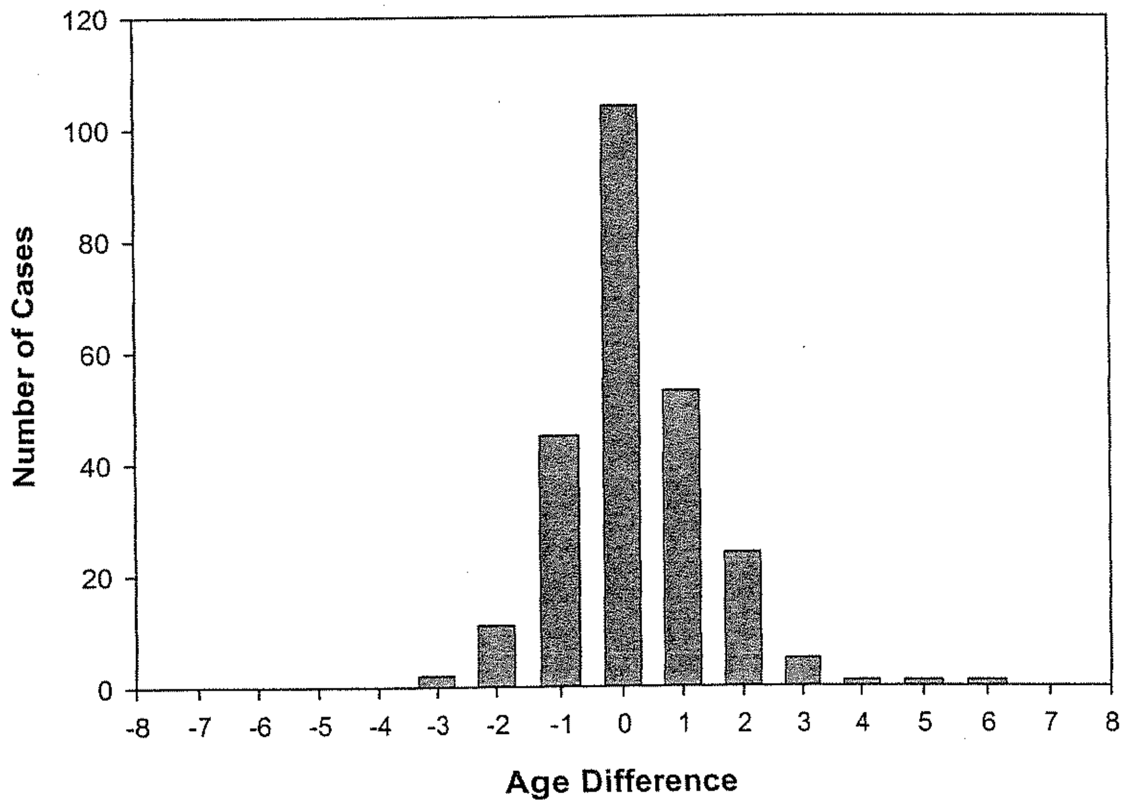


Figure 14. Magnitude of the age differences (otolith age – scale age) resulting from ageing specimens of striped bass (n=247) by reading both their scales and otoliths, spring, 2005.



II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring, 2004-2005

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Introduction

Striped bass (*Morone saxatilis*) have historically supported one of the most important recreational and commercial fisheries along the Atlantic coast. The species is one of the most important economical and social components of finfish catches in the Chesapeake Bay area. From 1965 to 1972, annual commercial landings of striped bass in Virginia fluctuated from about 554 to 1,271 metric tons (MT). Recreational harvests, although not well documented, may have reached equivalent levels (Field 1997). Beginning in 1973, a dramatic decrease in catches occurred, and during the period 1978 through 1985, annual commercial landings in Virginia averaged about 162 MT. This decline in Virginia's striped bass landings was reflected in similar catch statistics from Maine to North Carolina.

Concern about the decline in striped bass landings along the Atlantic coast since the mid-
1970's prompted the development of an interstate fisheries management plan (FMP) under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC) as part of their Interstate Fisheries Management Program (ASMFC 1981). Federal legislation was enacted in 1984 (Public Law 98-613, The Atlantic Striped Bass Conservation Act), which enables Federal imposition of a moratorium for an indefinite period in those states that fail to comply with the coastwise plan. To be in compliance with the plan, coastal states have imposed restrictions on their commercial and recreational striped bass fisheries ranging from combinations of catch quotas, size limits, and time-limited moratoriums to year-round moratoriums. The FMP was modified three times from 1984-1985 to further restrict fishing (Weaver *et al.* 1986). The first two amendments emphasized the need to reduce fishing mortality and to set target mortality rates. The third amendment was directed specifically at Chesapeake Bay stocks and focused on ensuring success of the 1982 and later year classes by recommending that states protect 95% of those females until they had the opportunity to spawn at least once.

Due to an improvement in spawning success, as judged by increases in annual values of the Maryland juvenile index, a fourth amendment to the FMP established a limited fishery in the fall of 1990. This transitional fishery existed until 1995 when spawning stock biomass in the Chesapeake Bay reached extremely healthy levels (Field 1997). The ASMFC subsequently declared Chesapeake stocks to have reached benchmark levels and the states adopted a fifth amendment to the original FMP in order to allow expanded state fisheries.

The Striped Bass Program of the Virginia Institute of Marine Science (VIMS) has monitored the size and age composition, sex ratio and maturity schedules of the spawning striped bass stock in the Rappahannock River since 1981. In conjunction with the monitoring studies, VIMS established a tagging program in 1988 to provide information on the migration, relative contribution to the coastal population, and annual survival of striped bass that spawn in the Rappahannock River. This program is part of an active cooperative tagging study that currently involves 15 state and federal agencies along the Atlantic coast. The U.S. Fish and Wildlife

Service manages the coast-wide tagging database. Hence, commercial and recreational anglers that target striped bass are encouraged to report all recovered tags to that agency. The analysis protocol, as established by the ASFMC Striped Bass Tagging Subcommittee, involves fitting a suite of reformulated Brownie models (Brownie et al. 1985; White and Burnham 1999) to the tag return data.

Although the initial purpose of the coast-wide tagging study was to evaluate efforts to restore Atlantic striped bass stocks (Wooley *et al.* 1990), tagging data are now being collected to monitor striped bass mortality rates in a recovered fishery. Thus far, these extensive data have not been formally summarized.

This section is an update material provided for this report by Latour (Sadler et al. 2001). He did a comprehensive analysis of the Rappahannock River striped bass tagging data, gave a detailed description of the ASFMC analysis protocol and presented annual survival (S) estimates derived from tag-recovery models developed by Seber (1970) as well as estimates of instantaneous fishing mortality (F) that followed when S was partitioned into its components using auxiliary information.

Multi-year Tagging Models

Tag return data is generally represented by constructing an upper triangular matrix of tag recoveries, where each cell of the matrix contains the number of tag returns from a particular year of tagging and recovery. For example, a study with I years of tagging and J years of recovery would yield the following data matrix

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1J} \\ - & r_{22} & \cdots & r_{2J} \\ \vdots & \vdots & \ddots & \vdots \\ - & - & - & r_{IJ} \end{bmatrix}, \qquad (1)$$

where r_{ij} is the number of tags recovered in year j that were released in year i (note, $J \geq I$). Tagging periods do not necessarily have to be yearly intervals; however, data analysis is easiest if all periods are the same length and all tagging events are conducted at the beginning of each period.

Application of tagging models involves constructing an upper triangular matrix of expected values and comparing them to the observed data. Since the data can be assumed to follow a multinomial distribution, the method of maximum likelihood can be used to obtain parameter estimates. Analytical solutions for the maximum likelihood parameter estimates are generally not available. Hence, several software packages that numerically maximize a product multinomial likelihood function have been developed for application of tagging models. They include programs SURVIV (White 1983), MARK (White and Burnham 1999), and AVOCADO (Hoenig et al. in prep.).

Seber models: White and Burnham (1999) reformulated the original Brownie et al. (1985) models in the way originally suggested by Seber (1970) to create a consistent framework for modeling mark-recapture data (Smith et al. 2000). This framework served as the foundation for program MARK, which is a comprehensive software package for the application of capture-recapture models. For time-specific parameterization of the Seber models, the matrix of expected values associated with equation (1) would be

$$E(R) = \begin{bmatrix} N_1(1-S_1)r_1 & N_1S_1(1-S_2)r_2 & \cdots & N_1S_1\cdots S_{J-1}(1-S_J)r_J \\ - & N_2(1-S_2)r_2 & \cdots & N_2S_2\cdots S_{J-1}(1-S_J)r_J \\ \vdots & \vdots & \ddots & \vdots \\ - & - & - & N_I(1-S_I)r_I \end{bmatrix}. \quad (2)$$

where N_i is the number tagged in year i, S_i is the survival rate in year i and r_i is the probability a tag is recovered from a killed fish regardless of the source of mortality.

The Seber models are simple and robust, but they do not yield direct information about exploitation (u) or instantaneous rates of mortality, which are often of interest to fisheries managers. Estimates S can be converted to the instantaneous mortality rate via the equation (Ricker 1975)

$$S = e^{-Z} \quad (3)$$

and, if information about the instantaneous natural mortality rate is available, estimates of the instantaneous fishing mortality can be recovered. Given estimates of the instantaneous rates, it is possible to recover estimates of u if the timing of the fishery (Type I or Type II) is known (Ricker 1975).

Instantaneous rate models: Hoenig et al. (1998a) modified the Brownie et al. (1985) models to allow for the estimation of instantaneous rates of fishing and natural mortality. This extension showed how information on fishing effort could be used as an auxiliary variable and also discussed generalizing the pattern of fishing within the year. The matrix of expected values corresponding to equation (1) for a model that assumes time-specific fishing mortality rates and a constant natural mortality rate would be

$$E(R)=\begin{bmatrix} N_1\phi\lambda u_1(F_1,M) & N_1\phi\lambda u_2(F_2,M)e^{-(F_1+M)} & \cdots & N_1\phi\lambda u_J(F_J,M)e^{-(\sum_{k=1}^{J-1}F_k+(J-1)M)} \\ - & N_2\phi\lambda u_2(F_2,M) & \cdots & N_2\phi\lambda u_J(F_J,M)e^{-(\sum_{k=2}^{J-1}F_k+(J-2)M)} \\ \vdots & \vdots & \ddots & \vdots \\ - & - & - & N_I\phi\lambda u_J(F_J,M) \end{bmatrix} \tag{4}$$

where ϕ is the probability of surviving being tagged and retaining the tag in the short-term, λ is the tag-reporting rate, and $u_k(F_k,M)$ is the exploitation rate in year k which, as mentioned above, depends on whether the fishery is Type I or Type II.

These models are not as simple as the Seber models, but they do yield direct estimates of F and, depending on the information available, either M or $\varphi\lambda$. Also, they can be parameterized to allow for non-mixing of newly and previously tagged animals (Hoenig *et al.* 1998b). If the goal of a particular tagging study is to estimate F and M, then auxiliary information on the tag reporting and tag-induced mortality/handling rate is required to apply the instantaneous rates formulation. However, if M is known, perhaps from a study that related it to life history characteristics (Beverton and Holt 1959; Pauly 1980; Hoenig 1983; Roff 1984; Gunderson and Dygert 1988), then these models can be used to estimate F and $\varphi\lambda$.

In either case, the auxiliary information needed (i.e., $\varphi\lambda$ or M) can often be difficult to obtain in practice, and since F, M and $\varphi\lambda$ are related functionally in the models, the reliability of the parameters being estimated is directly related to the accuracy of the estimated auxiliary parameter (Latour et al. 2001a).

Materials and Methods

Capture and Tagging Protocol

Each year from 1991 to 2005, during the months of March, April and May, VIMS scientists obtained samples of mature striped bass on the spawning grounds of the Rappahannock River. Samples were taken twice-weekly from pound nets owned and operated by a cooperating commercial fisherman. The pound net is a fixed trap that is presumed to be non-size selective in its catch of striped bass, and has been historically used by commercial fishermen in the Rappahannock River.

All captured striped bass were removed from each pound net and placed into a floating holding pocket (1.2m x 2.4m x 1.2m deep, with 25.4mm mesh and a capacity of approximately 200 fish) anchored adjacent to the gear. Fish were dip-netted from the holding pocket and examined for tagging. Fork length (FL) and total length (TL) measurements were taken and whenever possible the sex of each fish was determined. Striped bass not previously marked and larger than 458 mm TL were tagged with sequentially numbered internal anchor tags (Floy Tag and Manufacturing, Inc.). Each internal anchor tag was applied through a small incision in the abdominal cavity of the fish. A small sample of scales from between the dorsal fins and above the lateral line on the left side was removed and used to estimate age. Each fish was released at the site of capture immediately after receiving a tag.

Analysis protocol

ASMFC: TheASFMC Striped Bass Tagging Subcommittee established a data analysis protocol that involves deriving survival estimates from a suite of Seber (1970) models. The protocol is used by each state and federal agency participating in the cooperative tagging study. Tag recoveries from striped bass greater than 457 mm total length are analyzed from known producer areas (including Chesapeake Bay). Tag recoveries from striped bass that were greater than 711 mm total length (TL) at the time of tagging are analyzed from all coastal states since those fish are believed to be fully recruited to the fishery and also because they constitute the coastal migratory population (Smith *et al.* 2000).

The protocol consists of six steps. First, prior to data analysis, a set of biologically reasonable candidate models is identified. Characteristics of the stock being studied (i.e., Chesapeake Bay, Hudson River, Delaware Bay, etc.) and time are used as factors in determining the parameterizations of the candidate models. These models are then fit to the tagging data, and Akaike's Information Criterion (AIC) (Akaike 1973; Burnham and Anderson 1992), quasi-likelihood AIC (QAIC) (Akaike 1985), and goodness-of-fit (GOF) diagnostics are used to evaluate their fit (Burnham et al. 1995). The overall estimates of survival are calculated as a weighted average of survival from the best fitting models, where the weight is related to the model fit (i.e., the better the fit, the higher the weight) (Buckland et al. 1997; Burnham and Anderson 1998). The candidate models for striped bass survival (S) and tag recovery (r) rates are:

S(.)r(.)	Survival and tag-recovery rates are constant over time.
S(t)r(t)	Survival and tag-recovery rates are time-specific.
S(.)r(t)	Survival rate is constant and tag-recovery rates are time-specific.
S(p_1)r(t)	Survival rates vary by regulatory periods (p_1=constant 1990-1994 and 1995-2004) and tag-recovery rates are time-specific.
S(p_1)r(p_1)	Survival and tag-recovery rates vary by regulatory period.
S(.)r(p_1)	Survival rate is constant and tag-recovery rates vary by regulatory periods.

S(t)r(p_1)	Survival rates are time-specific and tag-recovery varies by regulatory periods.
S(p_2)r(p_1)	Survival and tag-recovery rates vary over different regulatory periods (p_2 = constant 1990-1994, 1995-2003 and 2004).
S(p_3)r(p_1)	Survival and tag-recovery rates vary over different regulatory periods (p_3 = constant 1990-1994, 1995-2002, 2003 and 2004).
S(Tp_1)r(Tp_1)	Survival and tag-recovery rates have linear trends within regulatory periods.
S(Tp_1)r(p_1)	Survival rates have a linear trend within regulatory periods and tag-recovery rates vary by regulatory period.
S(Tp_1)r(t)	Survival rates have a linear trend within regulatory periods and tag-recovery rates are time-specific.
S(p_4)r(p_4)	Survival and tag-recovery rates vary over regulatory periods (p_4 = constant 1990-1992, 1993-1994 and 1995-2004).

The striped bass tagging data contain a large number of tag-recoveries reflecting catch-and-release practices (i.e., the tag of a captured fish is clipped off for the reward and the fish released back into the population). Analysis utilizing these data leads to biased survival estimates if tag recoveries for re-released fish are treated as if the fish were killed. The fifth step applies a correction term (Smith *et al.* 2000) to offset the re-release-without-tag bias assuming a tag reporting rate of 0.43 (D. Kahn, Delaware Division of Fish and Wildlife, personal communication). The sixth step converts estimates of S_i to F_i via equation (3), assuming that $Z = F + M$ and M is 0.15 (Smith *et al.* 2000).

Dunning et al. (1987) quantified the rates of tag-induced mortality and tag retention for Hudson River striped bass. They found retention of internal anchor tags placed into the body cavity via an incision midway between the vent and the posterior tip of the pelvic fin was 98% for fish kept in outdoor holding pools for 180 days. Their holding experiment revealed that the survival rates of both tagged and control fish were not significantly different over a 24-hour period. A similar study conducted on resident striped bass within the York River, Virginia, yielded survival in the presence of tagging activity and short-term tag retention rates each in excess of 98% (Sadler et al. 2001). Based on these results, the ASMFC analysis protocol specifies making no attempts to adjust for the presence of short-term tag-induced mortality or acute tag-loss.

Results

Spring 2005 tag release summary

A total of 921 striped bass were tagged and released from the pound nets in the Rappahannock River between 28 March and 16 May, 2005 (Table 1). There were 637 resident striped bass (457-710 mm TL) tagged and released. These stripers were predominantly male (95.1%), but the female stripers were larger on average. The median date of these tag releases, to be used as the beginning of the 2005-2006 recapture interval, was 28 April. There were 284 migrant striped bass (>710 mm TL) tagged and released. These stripers were predominantly female (77.1%) and their average size was larger than for the male striped bass. The median date of these tag releases was 28 April.

Mortality estimates, 2004-2005

Tag recapture summary: A total of 80 (out of 1,447) resident striped bass (>458 mm TL), tagged during spring 2004, were recaptured between 19 April, 2004, and 27 April, 2005 (the respective midpoints of the two tag release totals), and were used to estimate mortality. Forty five of these recaptures were harvested (56.3%) and the rest were re-released into the population (Table 2). The proportion of tagged striped bass recaptured from 1991-2005 in their first year after release varied from 0.055 (80/1,447) to 0.111 (162/1.464). Since 1997, the initial recapture rates have only varied from 0.055-0.077. In addition, 62 striped bass tagged in previous springs were recaptured during the 2004-2005 recovery interval and were used to complete the input data matrix. The largest source of recaptures (59.9%) in the 2004-2005 recovery interval was Chesapeake Bay (41.6% in Virginia, 18.3% in Maryland, Table 3). Other recaptures came from New York (12.7%), Massachusetts (11.3%), New Jersey (4.2%), Rhode Island and North Carolina (3.5 % each), Delaware (2.8%), Connecticut (1.4%) and New Hampshire (0.7%). There was a primary peak of recaptures in May through July and a secondary peak in October through December.

A total of 39 (out of 686) migratory striped bass (>710 mm total length), tagged during spring 2004, were recaptured between 19 April, 2004, and 27 April, 2005 (the 2004-2005 recovery interval) and were used to estimate the mortality of this sub-group. Twenty one of these recaptures were harvested (53.8%), and the rest were re-released into the population (Table 4). The proportion of tagged striped bass recaptured from 1991-2005 in their first year after release varied from 0.015 (1/67) to 0.152 (24/158). In addition, 39 striped bass tagged in previous springs were recaptured during the recovery interval and were used to complete the input data matrix. Unlike 2004, the largest source (30.8%) of the recaptured tagged striped bass was Chesapeake Bay Virginia (24.4% in Virginia, 6.4% in Maryland, Table 5). Other recaptures came from New York (23.1%), Massachusetts (20.5%), New Jersey and Rhode Island (6.4% each), North Carolina (5.1%), Delaware (3.8%), Connecticut (2.6%) and New Hampshire (1.3%). The peak months for recaptures were May through July, but some migrant striped bass were recaptured from every month except February.

ASMFC protocol: Survival estimates were made utilizing the mark-recapture data for the Rappahannock River from 1990-2004. The suite of Seber (1970) models consisted of 13 models that each reflected a different parameterization over time. Models that allowed parameters to be both time-specific and constant across time were specified. Since Atlantic striped bass have been subjected to a variety of harvest regulations since 1990, it was hypothesized that these harvest regulations would influence survival and catch rates. Hence, models that allowed parameters to be constant for the time periods coinciding with stable coast-wide harvest regulations were also specified.

Prior to 2003, survival estimates from Virginia for striped bass greater than 457 mm (18") total length were suspect and not reported to the Stock Assessment Committee. Only one model (S(t) R(t)) fit the data and the previous results over time had spikes in survival (S) that were not possible (i.e. > 1.0). The 2003 *F* estimate was high (0.62), but this was likely over-estimated due to linear monotonic trend models (Welsh personal comm.). When the additional 2004 data was included, the 2003 *F* estimate was 0.12. In 2004, the S(t) R(t)model was again the only model to fit the data (Table 6). The 2004 *F* estimate was 0.49, the *S* estimate was 0.51, and none of the annual *S* estimates exceeded 1.0 (Table 7).

Survival estimates were obtained for striped bass greater than 710 mm (28") total length. Of the 13 proposed models, eight had ΔAICc values less than 7.0 (Table 8). A ΔAICc of 7.0 receives a weighting of 0.01 and is used as the threshold for inclusion in the analysis. Of the eight models, the calculated weight of the constant survival and two-period regulatory-based tag recovery model (i.e., S(.)r(p_1)) was slightly larger than the other models. Models that reflected more general time-specific parameterizations tended to not fit the data well. The ranking of the models, except for the constant survival and reporting model, was inversely related to the number of associated parameters.

The VIMS model-averaged estimates of the bias-adjusted survival rates for striped bass greater than 710 mm ranged from 0.606-0.658 over the time series (Table 9). The 2004 survival estimate was the highest in the time series. Otherwise, survival was highest during the transitional fishery and decreased slightly during the recovered fishery. This trend was the result of a higher proportion of annual tag recoveries being released back into the population in the early 1990's relative to more recent years. The corresponding estimates of $\hat{F}$ ranged from 0.115-0.335 and only infrequently, and by slight margins, exceeded the transitional and full fisheries target values.

Model evaluation

Latour et al. (2001b) proposed a series of diagnostics that can be used in conjunction with AIC and GOF measures to assess the performance of tag-recovery models. In essence, they suggested that the fit of a model could be critically evaluated by analyzing model residuals and that patterns would be evident if particular assumptions were violated.

For the time-specific Seber (1970) model, Latour et al. (2002) proved the existence of several characteristics about the residuals. Specifically, they showed that row and column sums of the residuals matrix must total zero, and further, they showed that the residuals associated with the "never seen again" category must also always be zero unless parameter estimates fall on a boundary condition. Latour et al. (2001c) also scrutinized the residuals associated with the instantaneous rates model and found the residual matrix of this model possessed fewer constraints than the time-specific Seber model. Although the row sums category must total zero, the column sums and the associated residuals can assume any value.

ASMFC protocol: Given that management regulations applied to striped bass during the 1990s have specified a wide variety of harvest restrictions, it would be reasonable to assume that the time-specific models (e,g. S(t)r(t), S(p_1)r(t), S(t)r(p_1), etc.) were most appropriate for data analysis. However, elements of the Rappahannock River tag-recovery matrix did not allow these models to adequately fit the data. The low total number tagged of striped bass releases, and the resultant low numbers of recaptures reported from the 1994 and 1996 cohorts (e.g. six from the 1996 cohort) relative to other years, may have resulted in the poor fit of the time-specific models. Unfortunately, numerical complications resulting from low sample size may have caused some of the more biologically reasonable models to not fit the Rappahannock River data well.

Discussion

The survival estimate for migrant striped bass for 2004-2005 was 0.658. The survival estimates for 2003 and 2004 are the highest in the time series and have incrementally increased every year since 1995. The estimate of fishing mortality for 2004-2005 was 0.225. The estimates of fishing mortality from 1990-2004 varied from 0.115-0.335 and exceeded the ASMFC threshold of 0.30 only in 1996 and 1997. Prior to 2004, the models that assume constant survival and/or reporting rate and the models that partition the time series into two periods (1990-1994 and 1995-2004) were found to best fit the data and contributed most heavily to the analysis (0.62 in 2003). These are the models that use the fewest parameters to produce the estimates of survival and fishing mortality. However, in 2004 the regulatory-based reporting rate models were the most heavily weighted (0.821).

Our analyses of the resident striped bass are problematic. The 2004-2005 estimates of survival (0.507) and fishing mortality (0.491) were derived after eliminating the time-dependent model (this model does not provide a terminal year estimate). However, in the original analysis this was the only model that the data fit (0.99996 of the weighting). While the new results for survival and fishing mortality, based mainly on the trend model, are plausible, the range of values are extreme, highly variable, and even include negative estimates of fishing mortality for other years. Given the poor fit on the data to the trend model in the original analysis, we have little confidence in the result. We intend to investigate the problems and their causes of these analyses and hopefully provide more credible future estimates.

Recently, we have begun using instantaneous rates models to study mortality rates of resident striped bass as an alternative to the Seber-Brownie models. These models are more efficient in that they require fewer parameters. This provides greater flexibility in modeling mortality over time. Preliminary results suggest that the models provide more reasonable results than the present method and that natural mortality is higher than previously thought and has been increasing over time. If true, then fishing mortality has been lower than previously estimated (Sadler, et al. 2004).

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Table 1. Summary data of striped bass tagged and released from pound nets in the Rappahannock River, spring 2005.

Date	total tagged	457 - 710 mm TL				> 710 mm TL			
		Males		females		males		females	
		n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$
28 March	96	80	511.4	1	612.0	2	792.5	13	883.1
31 March	114	82	528.2	3	624.2	8	803.8	21	901.8
4 April	46	25	539.8	2	631.5	2	821.0	17	907.2
7 April	94	72	497.8	3	552.3	4	794.5	15	899.9
11 April	13	5	510.8	0		0		8	940.3
14 April	17	8	539.5	0		1	796.0	8	939.4
18 April	13	2	577.0	0		0		11	927.9
21 April	30	13	560.8	1	564.0	1	728.0	15	883.9
25 April	63	29	563.9	4	607.5	8	796.0	22	879.1
28 April	108	63	547.7	3	615.0	11	809.1	31	899.1
2 May	51	37	544.1	3	548.0	2	812.5	9	915.0
5 May	58	31	552.6	2	562.5	10	817.2	15	898.2
9 May	116	82	572.9	2	551.5	12	786.9	20	874.8
12 May	63	53	555.0	0		3	783.7	7	866.3
16 May	39	24	571.6	7	610.1	1	725.0	7	823.0
Total	921	606	539.8	31	593.1	65	701.2	219	830.3

Table 2. Recapture matrix of striped bass (>457 mm TL) that were released in the Rappahannock River, springs 1990-2004. The second (bottom) number is the number of those recaptures that were harvested.

Year	n	recaptures														
		90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
1990	1,464	162 21	64 20	47 24	25 10	12 8	10 9	3 2	2 0	3 0	1 1	1 1	0 0	0 0	1 1	0 0
1991	2,481		167 48	81 38	53 22	29 14	6 3	5 5	2 2	2 1	4 0	1 0	0 0	0 0	1 1	0 0
1992	130			14 7	8 4	6 1	5 3	1 0	1 0	1 0	1 1	0 0	0 0	0 0	0 0	0 0
1993	621				50 18	37 17	17 12	8 5	9 4	2 1	0 0	1 0	0 0	0 0	0 0	0 0
1994	195					13 6	10 7	5 4	4 1	4 2	0 0	0 0	0 0	0 0	0 0	0 0
1995	698						55 24	30 12	20 9	5 4	4 1	2 1	3 2	0 0	1 1	0 0
1996	376							21 3	18 10	7 3	3 2	1 1	1 1	1 1	0 0	0 0
1997	712								47 26	26 17	14 10	3 2	0 0	1 1	2 1	1 1
1998	784									55 28	26 16	2 1	3 3	3 1	1 0	0 0
1999	853										66 30	23 7	9 4	5 2	3 2	0 0
2000	1,765											122 44	51 23	23 11	16 7	6 4
2001	797												61 32	23 14	16 5	7 7
2002	315													20 10	8 4	15 6
2003	852														58 32	33 20
2004	1,447															80 45

Table 3. Location of striped bass (> 457 mm TL), recaptured in 2005, that were originally tagged and released in the Rappahannock River during springs 1988-2004 and used for mortality analysis.

State	Month												total
	J	F	M	A	M	J	J	A	S	O	N	D	
N. Hampshire	0	0	0	0	0	1	0	0	0	0	0	0	1
Massachusetts	0	0	0	0	2	3	8	2	1	0	0	0	16
Rhode Island	0	0	0	0	0	1	2	1	1	0	0	0	5
Connecticut	0	0	0	0	0	0	1	0	1	0	0	0	2
New York	0	0	0	0	4	4	2	1	2	3	2	0	18
New Jersey	0	0	0	0	2	1	1	0	0	0	2	0	6
Delaware	0	0	0	0	0	2	0	0	0	1	1	0	4
Maryland	0	0	0	1	5	12	6	0	0	2	0	0	26
Virginia	1	0	4	10	8	9	3	1	0	7	8	8	59
North Carolina	3	0	0	0	0	0	0	0	0	0	0	2	5
Total	4	0	4	11	21	33	23	5	5	13	13	10	142

Table 4. Recapture matrix of striped bass (>710 mm TL) that were released in the Rappahannock River, springs 1990-2004. The second (bottom) number is the number of those recaptures that were harvested.

Year	n	recaptures														
		90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
1990	301	26 10	9 2	15 6	2 1	4 3	6 5	1 1	0 0	2 0	1 1	1 1	0 0	0 0	1 1	0 0
1991	390		41 19	24 10	16 12	11 9	3 2	2 1	2 2	1 0	2 2	0 0	0 0	0 0	1 1	0 0
1992	40			4 2	3 1	2 1	2 1	0 0	0 0	0 0	0 0	1 1	0 0	0 0	0 0	0 0
1993	212				22 11	18 11	7 5	4 2	7 3	0 0	0 0	1 0	0 0	0 0	0 0	0 0
1994	123					9 4	7 4	5 4	1 1	2 0	0 0	0 0	0 0	0 0	0 0	0 0
1995	210						29 18	11 6	8 5	3 2	3 1	2 1	3 2	0 0	1 1	0 0
1996	67							1 1	3 3	1 1	0 0	0 0	1 1	0 0	0 0	0 0
1997	212								15 11	13 12	8 6	3 2	0 0	1 1	2 1	1 1
1998	158									24 16	13 9	2 1	3 3	2 1	0 0	0 0
1999	162										17 13	6 2	2 1	3 2	2 1	0 0
2000	365											28 13	19 11	14 6	9 5	4 3
2001	269												19 9	14 8	4 2	6 6
2002	122													10 7	6 3	7 5
2003	400														35 23	21 13
2004	686															39 21

Table 5. Location of striped bass (> 710 mm TL), recaptured in 2005, that were originally tagged and released in the Rappahannock River during springs 1988-2004 and used for mortality analysis.

State	Month												total
	J	F	M	A	M	J	J	A	S	O	N	D	
N. Hampshire	0	0	0	0	0	1	0	0	0	0	0	0	1
Massachusetts	0	0	0	0	2	3	8	2	1	0	0	0	16
Rhode Island	0	0	0	0	0	1	2	1	1	0	0	0	5
Connecticut	0	0	0	0	0	0	1	0	1	0	0	0	2
New York	0	0	0	0	4	4	2	0	2	4	2	0	18
New Jersey	0	0	0	0	2	1	1	1	0	0	1	0	5
Delaware	0	0	0	0	0	2	0	0	0	0	1	0	3
Maryland	0	0	0	1	3	1	0	0	0	0	0	0	5
Virginia	0	0	1	5	2	4	0	0	0	1	2	4	19
North Carolina	2	0	0	0	0	0	0	0	0	0	0	2	4
Total	2	0	1	6	13	16	14	4	5	5	6	6	78

Table 6. Performance statistics (>457 mm TL), based on quasi-likelihood Akaike Information Criterions (QAIC), used to assess the Seber (1970) models utilized in the ASMFC analysis protocol. Model notations: S (f) and r (f) indicate that survival (S) and tag-reporting rate (r) are functions (f) of the factors within the parenthesis; constant parameters across time (.); parameters constant from 1990-1994 and 1995-2004 (p_1); parameters vary in 2004 (p_2), otherwise the same as p_1; parameters vary in 2003 and 2004 (p_3), otherwise the same as p_1; parameters constant from 1990-1992, 1993-1994 and 1995-2004 (p_4); assumption of linear trends from 1990-1994 and 1995-2004 (Tp_1); and parameters are time-specific (t).

Model	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ weight	number of parameters
S(t)r(t)	10527.18	0.00	0.99996	29
S(p_1)r(t)	10550.04	22.86	0.00001	17
S(p_4)r(p_4)	10551.80	24.61	0.00000	6
S(Tp_1)r(Tp_1)	10551.97	24.67	0.00000	8
S(Tp_1)r(t)	10552.21	25.02	0.00000	19
S(.)r(t)	10552.23	25.04	0.00000	16
S(p_1)r(p_1)	10552.25	25.07	0.00000	4
S(T_{p1})r(p_1)	10552.74	25.55	0.00000	6
S(p_2)r(p_1)	10553.66	26.48	0.00000	5
S(t)r(p_1)	10553.99	26.81	0.00000	17
S(p_3)r(p_1)	10555.15	27.97	0.00000	6
S(.)r(p_1)	10558.00	30.81	0.00000	3
S(.)r(.)	10576.99	49.81	0.00000	2

Table 7. Seber (1970) model estimates (VIMS) of unadjusted survival ($\hat{S}$) rates and adjusted rates of survival ($\hat{S}_{adj}$) and fishing mortality ($\hat{F}$) of striped bass (> 457 mm FL) derived from the proportion of recaptures released alive (P_l) in the Rappahannock River, 1990-2004.

Year	$\hat{S}$	SE ($\hat{S}$)	P_l	bias	$\hat{S}_{adj}$	$\hat{F}$	95%CI $\hat{F}$
1990	0.816	0.086	0.481	-0.143	0.952	-0.101	-0.23, 0.23
1991	0.276	0.051	0.524	-0.082	0.301	1.051	0.71, 1.44
1992	0.804	0.164	0.408	-0.142	0.938	-0.086	-0.27, 0.75
1993	0.604	0.131	0.456	-0.105	0.675	0.243	-0.06, 0.81
1994	0.573	0.128	0.381	-0.087	0.628	0.316	0.00, 0.88
1995	0.689	0.138	0.262	-0.054	0.728	0.167	-0.08, 0.75
1996	0.623	0.130	0.274	-0.039	0.648	0.273	0.00, 0.84
1997	0.561	0.106	0.330	-0.058	0.595	0.369	0.08, 0.83
1998	0.408	0.078	0.362	-0.060	0.434	0.685	0.36, 1.11
1999	0.373	0.066	0.286	-0.060	0.396	0.776	0.46, 1.16
2000	0.422	0.065	0.436	-0.074	0.456	0.636	0.37, 0.97
2001	0.457	0.101	0.367	-0.069	0.490	0.562	0.21, 1.07
2002	0.647	0.150	0.368	-0.064	0.692	0.219	-0.08, 0.87
2003	0.723	0.157	0.271	-0.048	0.760	0.124	-0.12, 0.82
2004	0.507	0.035	0.267	-0.037	0.527	0.491	0.36, 0.64

Table 8. Performance statistics (>711 mm TL), based on quasi-likelihood Akaike Information Criterions (QAIC), used to assess the Seber (1970) models utilized in the ASMFC analysis protocol. Model notations: S (f) and r (f) indicate that survival (S) and tag-reporting rate (r) are functions (f) of the factors within the parenthesis; constant parameters across time (.); parameters constant from 1990-1994 and 1995-2004 (p_1); parameters vary in 2004 (p_2), otherwise the same as p_1; parameters vary in 2003 and 2004 (p_3), otherwise the same as p_1; parameters constant from 1990-1992, 1993-1994 and 1995-2004 (p_4); assumption of linear trends from 1990-1994 and 1995-2004 (Tp_1); and parameters are time-specific (t).

Model	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ weight	number of parameters
S(.)r(p_1)	4205.92	0.00	0.19132	3
S(p_3)r(p_1)	4205.94	0.02	0.18973	5
S(Tp_1)r(p_1)	4206.12	0.20	0.17307	6
S(p_2)r(p_1)	4206.41	0.49	0.15011	5
S(p_1)r(p_1)	4206.92	1.00	0.11588	4
S(.)r(.)	4207.18	1.26	0.10202	2
S(Tp_1)r(Tp_1)	4208.70	2.78	0.04776	8
S(p_4)r(p_4)	4209.77	3.85	0.02787	6
S(.)r(t)	4216.71	10.79	0.00087	17
S(p_1)r(t)	4217.14	11.22	0.00070	17
S(t)r(p_1)	4217.86	11.94	0.00049	17
S(Tp_1)r(t)	4220.16	14.23	0.00016	19
S(t)r(t)	4224.81	18.88	0.00012	29

Table 9. Seber (1970) model estimates (SBTC) of unadjusted survival ($\hat{S}$) rates and adjusted rates of survival ($\hat{S}_{adj}$) and fishing mortality ($\hat{F}$) of striped bass (> 711 mm FL) derived from the proportion of recaptures released alive (P_l) in the Rappahannock River, 1990-2004.

Year	$\hat{S}$	SE ($\hat{S}$)	P_l	bias	$\hat{S}_{adj}$	$\hat{F}$	95%CI
1990	0.635	0.032	0.577	-0.127	0.727	0.169	0.08, 0.27
1991	0.635	0.028	0.560	-0.131	0.730	0.164	0.08, 0.26
1992	0.635	0.026	0.535	-0.172	0.767	0.115	0.04, 0.20
1993	0.637	0.029	0.349	-0.093	0.702	0.204	0.12, 0.30
1994	0.637	0.033	0.318	-0.070	0.685	0.228	0.14, 0.34
1995	0.603	0.031	0.204	-0.078	0.654	0.275	0.18, 0.38
1996	0.606	0.027	0.125	-0.016	0.616	0.335	0.25, 0.43
1997	0.610	0.024	0.167	-0.037	0.633	0.307	0.23, 0.39
1998	0.613	0.022	0.217	-0.086	0.671	0.250	0.18, 0.33
1999	0.616	0.023	0.200	-0.057	0.654	0.275	0.21, 0.35
2000	0.620	0.025	0.348	-0.072	0.668	0.254	0.18, 0.34
2001	0.623	0.028	0.298	-0.052	0.657	0.270	0.19, 0.36
2002	0.626	0.031	0.295	-0.077	0.678	0.238	0.15, 0.34
2003	0.639	0.041	0.246	-0.057	0.678	0.238	0.13, 0.38
2004	0.658	0.049	0.295	-0.043	0.687	0.225	0.10, 0.38

III. Fishing mortality estimates in the fall, 2004, resident striped bass fishery in Chesapeake Bay, Virginia.

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Introduction

In contrast to the highly migratory, mostly female, coastal striped bass population, the Chesapeake Bay and its tributaries consists of a resident population of mature male striped bass in addition to pre-migrant (<2 years old), immature striped bass of both sexes. These resident striped bass evidently exhibit little movement during the summer and early fall, remaining stationary in areas of abundant forage (Merrimen 1941, Vladykov and Wallace 1938, Mansueti 1961). In late fall, in response to falling water temperatures and movement of the schools of baitfish, resident striped bass migrate downriver to deeper parts of the tributaries and generally southward along the western side of Chesapeake Bay to over-winter in deeper portions of the bay (Vladykov and Wallace 1938, Mansueti 1961). These striped bass, supplemented by an infusion of southward migrating coastal fish in late November and December, form the basis of the historic annual fall recreational and commercial fisheries.

In 1993, the rebound in striped bass abundance allowed for a lifting of the moratorium on the recreational fishery. The Atlantic States Marine Fisheries Commission (ASMFC) established a target fishing mortality rate (F) of 0.25/yr., which was further relaxed to a rate of 0.30 in 1995 in response to evidence of continued stock recovery (Field 1997). To document compliance with the ASMFC regulations, the VIMS Anadromous Fishes Program modified its fall tagging methodology, begun in 1987, to collaborate with the Maryland Department of Natural Resources (Md DNR) to estimate the recreational fishing mortality rate for Chesapeake Bay.

Materials and Methods

Experimental design

Commencing in 1995, a stratified tag release program was instituted in collaboration with Maryland DNR. The Virginia portion of the Chesapeake Bay was divided into the York, James and Rappahannock rivers and (western) upper and middle main-stem Chesapeake Bay (Fig. 1). Multiple, short-duration (< 10 days) tag release periods, synchronized with the Md DNR effort and separated by 3-4 weeks, were executed with the first tagging round occurring prior to the start of each fall recreational season (4 Oct in Virginia). The multiple-release protocol minimized the effects of immigration and emigration in the analysis. Optimal tagging quotas, proportionally based on historic catch data, were allotted to each area to facilitate the diffusion of tagged fish throughout Chesapeake Bay. From 1995-2004, striped bass were tagged from commercial pound nets, drift gill nets, fyke nets and haul seines at multiple sites within each system.

General protocols for tagging follow those described in previous mark-recovery studies (Rugulo et al. 1994, Shaefer and Rugulo 1996, Herbert et al. 1997). A Floy internal tag, with dimensions of 5 mm x 15 mm with an 85 mm external tube was used. Tags were inserted into the peritoneal cavity posterior to the pectoral fin on the left side of the fish. Lengths (FL, TL) were recorded for each striped bass and a scale sample was taken from between the two dorsal fins and above the lateral line for subsequent aging of the fish (Merrimen 1941). Only striped bass greater than 458 mm total length (18 inches) were tagged. Physical parameters (time, air and surface water temperatures, and tidal stage) were recorded at each tagging location.

Analytical methods

Commencing in 1997, the bay-wide estimate of fishing mortality for resident striped bass has been based on pooled data from the coordinated multiple-release tagging study in addition to harvest statistics from both states from the spring of the subsequent year. The bay-wide estimates are annual mortality rates. They pertain to a 12-month period that begins and ends in the late spring of each year (1 June - 31 May).

For purposes of tag release, the natural boundary between Maryland and Virginia was used to stratify Chesapeake Bay into two management jurisdictions. Despite having separate management jurisdictions, tagging efforts were synchronized during times when the fishing seasons on the two states overlapped. In all years, the first release in each jurisdiction began approximately one week prior to the start of the recreational season. The recovery interval began the day after at least one half of the stripers were tagged on a bay-wide basis in each release interval and continued up to the start of the next interval.

The tagging study requires making the assumption that the tagging process does not affect the behavior or the survival of the tagged fish and that there is no tag loss. Assessment of the short-term tag-induced mortality was done in Maryland (1995), and in Virginia (2000), and produced tagging mortality rates of 1.3% and 1.5% respectively (Latour *et al.* in prep). Determination of the reporting rate of recaptured tagged striped bass was done in 1999 by comparing the observed reporting rate with that of a subset of high-reward tags released simultaneously. The resulting tag reporting rates were 0.64 and 0.55 depending on the recovery interval specified (Rogers *et al.* 2000).

Tag recovery data were provided to the Md DNR for estimation of exploitation rate (U) and instantaneous fishing mortality (F). Estimates were calculated utilizing a logistic regression model based on reported tag recoveries that occurred between the midpoints (the date after which 50% of tag releases occurred) of consecutive tagging rounds. The proportion of the number of tags recovered to the number of tags released was the response variable and the explanatory variables consisted of one categorical variable (interval number) and two binary variables (disposition of the recapture and angler type). Note, however, that this procedure is identical to calculating simple ratios of recaptured to marked individuals. The logistic regression is simply an artifact from an earlier time when the incorporation of additional factors was contemplated. Tag release and recovery data for input into the model were adjusted to eliminate the following tag recoveries: those that occurred between the start of the tagging round but prior to the day after the midpoint of tag releases for that round; from stripers found dead or if only a tag was recovered (as opposed to a tagged striper, Goshorn, *et al.* 1999). The calculation of the recreational exploitation rate used only tag returns from striped bass harvested by recreational and charter fishermen.

Results

Tag release summary

In fall 2004, a total of 3,434 striped bass were tagged and released among three tagging rounds in Virginia. The high variability of tag releases among the three rounds normally reflect the seasonal availability of striped bass to the commercial gears utilized in each sampling area.

Tagging round 4, 20-29 September: The 899 striped bass tagged and released came primarily (52.6%) from middle Chesapeake Bay locations (Table 1). Only the two Chesapeake Bay jurisdictions exceeded their desired quotas. This overall lack of spatial diversity is typical of previous tagging rounds in September, but the striped bass normally caught in abundance in the upper Rappahannock River were caught in unusually low numbers. The haul seines in the James River were also less successful than had been the case in previous September tagging rounds. The highest single day tagging total was on 24 September (Table 2) and this date was the midpoint for the fourth tagging round.

Water temperatures during the tagging round were 22-24 °C. As water temperatures drop during October, the striped bass form large schools and migrate towards the deeper, open waters in the lower rivers and Chesapeake Bay and are more susceptible to capture in commercial gears.

The majority of the striped bass tagged and released were from the 2001 (63.6%) and 2000 (29.6%) year classes (Table 3). The mean ages of the striped bass from each jurisdiction varied from only 3.28 years (Rappahannock River) to 3.65 years (York River). The mean size (FL) of the striped bass tagged and released from each jurisdiction varied from 472.9 mm (Rappahannock River) to 504.0 mm (York River).

Tagging round 5, 18-27 October: There was 1,383 striped bass tagged and released during the tagging interval. This reflects the typical increase in availability relative to September or early October (Table 1). Unfortunately, the striped bass catches in the upper Rappahannock River had remained low after the fourth tagging round was completed and the fishermen ceased fishing. However, except for the James River, the other tagging jurisdictions exceeded their quotas. The most successful tagging date was 19 October (Table 4) and this was the midpoint of the fifth tagging round. Water temperatures during the tagging round were 15-18 °C.

The majority of the striped bass tagged and released were from the 2001 (71.2%) and 2000 (27.3%) year classes (Table 5). The mean ages of the striped bass from each jurisdiction varied from only 3.28 years (middle Chesapeake Bay) to 3.48 years (James River). The mean sizes (FL) of the striped bass tagged and released from each jurisdiction varied from 484.7 mm (middle Chesapeake Bay) to 495.7 mm (James River).

Tagging round 6, 17-26 November: There was 1,152 striped bass tagged and released in this tagging interval. This final tagging round used a different strategy relative to the previous tagging rounds. First, the Thanksgiving holidays (24-26 November) reduced the number of tagging days available. In addition, a northeaster on 19 November was followed by unusually cold weather through the rest of the tagging round. Striped bass, usually abundant at most tagging locations, evidently moved into deeper waters away from our commercial gears. This was especially true for the haul seines utilized in the James River, and resulted in a failure to reach the desired release quotas in all jurisdictions except in the middle Chesapeake Bay (Table 1). However, striped bass were abundant in the pound nets near the mouth of the Rappahannock River, so additional fish were tagged there to supplement the loss from the other areas. The most successful tagging date was 18 November and this was the midpoint of the sixth tagging round. Water temperatures during the tagging round ranged from 11-13 °C.

The majority of the striped bass tagged and released were from the 2001 (61.7%) and 2000 (31.5%) year classes (Table 7). The mean ages of the striped bass from each jurisdiction varied from 3.09 years (York River) to 3.80 years (James River). The mean sizes of the striped bass tagged and released from each jurisdiction varied from 456.7 mm (York River) to 523.4 mm (James River).

Tag recapture summary

A total of 145 of the striped bass tagged during the fall were recaptured from 20 September - 31 December, 2004 (Table 8). The overall proportion recaptured was 0.042 and varied by jurisdiction from 0.020 (upper Chesapeake Bay) to 0.220 (York River). All recaptures from the James and upper Rappahannock rivers were recaptured within the same area they were tagged. Striped bass tagged in the York River were predominantly recaptured there (0.949), but were also recaptured in the lower Chesapeake Bay. Striped bass tagged near the mouth of the Rappahannock River (middle Chesapeake Bay) were predominantly recaptured in the lower Rappahannock River (0.739), but were also recaptured in the lower Chesapeake Bay (0.109), middle and upper Chesapeake Bay (0.065 each) and the Potomac River (0.022). Striped bass tagged and released in the upper Chesapeake Bay were mostly recaptured there (0.471) but were also recaptured in Maryland (0.176), James River (0.118), middle Chesapeake Bay, lower Chesapeake Bay, Potomac River and the Atlantic Ocean (0.059 each). The striped bass recaptured from James River releases were slightly larger and older than the striped bass recaptured from the other areas.

Recapture interval 4, 25 September-19 October: A total of 78 striped bass (8.7%) that were tagged in the fourth tagging round were recaptured by 31 December (0.08% per day). Forty one of these recaptures occurred within the fourth recapture interval (Table 9). Most (95.1%) recaptures came from the pound nets from which the striped bass were obtained for tagging. Sport fishermen (recreational and charter anglers) accounted for only 4.9% of the recaptures during the fourth recapture interval. These anglers harvested all of these recaptured tagged striped bass. These two recaptured striped bass harvested by sport fishermen were the data used in the computation of fishing mortality. The "other" category consisted mainly of recaptured striped bass encountered by VIMS tagging personnel at our research pound net in the York River or at the nets of cooperating fishermen at our tagging locations. These fish were re-released unharmed if deemed robust by the chief scientist in each tagging party.

Recapture interval 5, 20 October-18 November: A total of 54 striped bass (3.9%) that were tagged in the sixth tagging round were recaptured by 31 December (0.05% per day). Thirty five of these recaptures (64.8%) occurred within the fifth recovery interval, mostly from the pound nets from which they were tagged (Table 10). Sport fishermen accounted for only 20.0% of the recaptures during the fifth recapture interval. Less than half (42.9%) of the recaptured striped bass caught by anglers were harvested. These three recaptured striped bass harvested by sport fishermen were the data used in the computation of fishing mortality.

Recapture interval 6, 19 November - 31 December: A total of 13 striped bass (1.1%) that were tagged in the seventh tagging round were recaptured by 31 December (0.03% per day). By design, all the recaptures occurred within the recovery interval (Table 11). Sport fisherman accounted for 38.5% of the recaptures during the recapture interval and released more than half. The two recaptured striped bass harvested by sport fishermen were the data included in the computation of fishing mortality.

Estimation of fishing mortality (F)

To obtain an estimate of fishing mortality, the tag-recovery rate f_i must first be converted to a finite exploitation rate (Pollock *et al.* 1991):

$$u_i = \frac{f_i}{\lambda_R}$$

where u_i is the fall recreational/charter exploitation rate in interval i and λ_R is the probability a recreational angler will report a tag recapture given that a tagged fish has been caught. Since the recovery interval was of short duration (20-40 days), natural mortality was deemed negligible and a type I (pulse) fishery was presumed to exist. The fishing mortality rate was then calculated as (Ricker 1975):

$$F = -\sum_{i=1}^{L} \log(1 - u_i)$$

where L is the total number of intervals.

Recreational fishing also occurs in the spring when tagging of the resident striped bass is not conducted. Hence, derivation of an overall resident fishing mortality rate was adjusted by:

$$F_r = F + (FP_S)$$

where F_r is the overall recreational/charter fishing mortality rate and P_S is the proportion of the number of resident striped bass in the spring harvest relative to the total recreational harvest. Harvest statistics were obtained from the Marine Fisheries Recreational Statistics Survey (MRFSS).

The estimate of the Chesapeake Bay fishing mortality rate for 2004 was 0.06. A non-harvest mortality rate of 0.10 was added to produce the final estimate of a recreational/charter fishing mortality of 0.16 (Hornick *et al.* 2005).

Discussion

The number of striped bass tagged during the three tagging rounds in Virginia is generally a reflection of their areal and seasonal availability. In September, striped bass are generally scattered in small schools and are structure oriented. Usually striped bass are reliably captured in quantity from the pound nets of our cooperating fisherman in the upper Rappahannock River and occasionally from haul seines in some shallow bays in the middle James River, but are scarce and sporadic elsewhere. By late October falling water temperatures and the first fall storms apparently initiates a schooling and feeding response in striped bass and they become susceptible to commercial gears throughout western Chesapeake Bay. This trend generally continues through Thanksgiving, but most poundnetters start removing their nets in early November in response to falling catches in the general fisheries and to reduce exposing nets to potential damage from coastal storms. However, striped bass were less abundant in the middle James and upper Rappahannock rivers in 2004. Therefore the majority of the striped bass were tagged in the two Chesapeake Bay jurisdictions.

Both pound nets and haul seines are non size-selective, but the legal-sized (>458 mm FL) striped bass captured for tagging were overwhelmingly three and four year-old fish. Larger resident male striped bass are encountered in the spring tagging and spawning stock assessment studies, so their omission may create a size-bias in the estimation of fishing mortality of the resident population. Larger fish immigrate from coastal waters into Chesapeake Bay in late November and are generally targeted by recreational anglers. Historically, these striped bass are less likely to be released when captured.

The high incidence of recapture of tagged striped bass within the same general geographic area in which they were released in the first two tagging rounds in Virginia (rounds five and six) indicate that the early fall migrations of the resident population is limited in scope (see Figure 1 for the areal breakdown). The prevalence of same-area recapture was highest in York River and was also very high in the pound nets at the mouth of the Rappahannock River. However, striped bass tagged from our upper Chesapeake Bay locations did show a wider pattern of dispersal. Striped bass tagged there were recaptured throughout the Chesapeake Bay (including Maryland) as well as in the James and Rappahannock rivers.

The Chesapeake Bay-wide estimate of resident striped bass fishing mortality was 0.16. This was the sum of the estimate of both non-harvest (0.10) and harvest (0.06) mortalities. Non harvest mortalities include natural deaths and handling-induced mortalities. In our fall 2004 study, 85.5% of the recaptures were released alive (50.0% of sport recaptures and 100% of research recaptures). The fishing mortality estimate was below the target rate (0.30) desired for Chesapeake Bay established by the Atlantic States Marine Fisheries Commission (ASMFC).

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Table 1. Striped bass tag release round dates, proposed tag release quotas and number of striped bass tagged and released in Chesapeake Bay, Virginia, fall, 2004. Note: tagging rounds 1-3 were in Maryland only.

Tagging round	Dates	Location	Quota	Releases
4	20-29 Sep.	Chesapeake Bay – upper	150	192
		Chesapeake Bay – middle	150	473
		Rappahannock River	350	90
		York River	100	68
		James River	250	76
		Subtotal	1,000	899
5	18-27 Oct.	Chesapeake Bay - upper	300	632
		Chesapeake Bay - middle	200	553
		Rappahannock River	300	0
		York River	100	145
		James River	300	53
		Subtotal	1,200	1,383
6	17-26 Nov.	Chesapeake Bay - upper	300	137
		Chesapeake Bay - middle	200	955
		Rappahannock River	200	0
		York River	100	55
		James River	200	5
		Subtotal	1,000	1,152

Table 2. Daily striped bass tag release totals, by area, during round four (20-29 September) of the fall, 2004 fishing mortality (F) study.

Tag release area	20 Sep	21 Sep	22 Sep	23 Sep	24 Sep	25 Sep	26 Sep	27 Sep	28 Sep	29 Sep
Chesapeake Bay (upper region)					113			37		42
Chesapeake Bay (middle region)		130			161			81		101
Rappahannock River (upper region)	49							41		
York River (middle region)		14			30				24	
James River (middle region)	1		75							
totals	50	144	75	0	304	0	0	159	24	143

Table 3. Age structure, by year class (YC), and mean fork length (FL, in mm) of striped bass tagged and released at each location during round four (20-29 September) of the fall, 2004 fishing mortality study.

Tagging location	Year class	n	%	Mean FL (mm) YC	Mean FL (mm) total	Mean age
Chesapeake Bay (upper region)	2001	116	60.4	458.6	482.9	3.43
	2000	69	35.9	515.3		
	1999	7	3.6	567.3		
Chesapeake Bay (middle region)	2001	304	64.3	456.1	478.3	3.37
	2000	146	30.9	514.5		
	1999	12	2.5	554.9		
	1998	1	0.2	677.0		
	n/aged	10	2.1	514.7		
Rappahannock River (upper section)	2001	65	72.2	453.9	472.9	3.28
	2000	21	23.3	520.1		
	1999	2	2.2	596.5		
	n/aged	2	2.2	470.5		
York River (middle section)	2001	33	48.5	454.9	504.0	3.65
	2000	27	39.7	529.9		
	1999	6	8.8	602.2		
	1998	1	1.5	633.0		
	1997	1	1.5	710.0		
James River (middle section)	2001	46	60.5	455.8	483.7	3.43
	2000	26	34.2	519.7		
	1999	3	3.9	608.3		
	n/aged	1	1.3	456.0		

Table 4. Daily striped bass tag release totals, by area, during round five (18-27 October-5) of the fall, 2004 fishing mortality (F) study.

Tag release area	18 Oct	19 Oct	20 Oct	21 Oct	22 Oct	23 Oct	24 Oct	25 Oct	26 Oct	27 Oct
Chesapeake Bay (upper region)	264							386		
Chesapeake Bay (middle region)		553								
Rappahannock River										
York River		102			18				25	
James River (middle region)	36		17							
totals	300	655	17	0	18	0	0	386	25	0

Table 5. Age structure, by year class (YC), and mean fork length (FL, in mm) of striped bass tagged and released at each location during round five (18-27 October) of the fall, 2004 fishing mortality study.

Tagging location	Year class	n	%	Mean FL (mm) YC	Mean FL (mm) total	Mean age
Chesapeake Bay (upper region)	2001	441	69.8	460.8	478.0	3.29
	2000	166	26.3	518.1		
	1999	6	9.5	587.2		
	n/aged	19	3.0	491.6		
Chesapeake Bay (middle region)	2001	196	35.4	457.4	474.7	3.28
	2000	63	11.4	517.8		
	1999	5	0.9	566.8		
	n/aged	289	52.3	475.5		
York River (middle section)	2001	96	66.2	458.3	480.2	3.35
	2000	44	30.3	517.8		
	1999	3	2.1	624.7		
	n/aged	2	1.4	489.5		
James River (middle section)	2001	30	56.6	465.1	495.7	3.48
	2000	20	37.7	528.2		
	1999	1	1.9	540.0		
	1998	1	1.9	723.0		
	n/aged	1	1.9	493.0		

Table 6. Daily striped bass tag release totals, by area, during round six (17-25 November) of the fall, 2004 fishing mortality (F) study.

Tag release area	17 Nov	18 Nov	19 Nov	20 Nov	21 Nov	22 Nov	23 Nov	24 Nov	25 Nov	26 Nov
Chesapeake Bay (upper region)	137									
Chesapeake Bay (middle region)		539				416				
Rappahannock River (upper region)										
York River (middle region)	43		6							
James River (middle region)	5					6				
totals	185	539	6	0	0	422	0	0	0	0

Table 7. Age structure, by year class (YC), and mean fork length (FL, in mm) of striped bass tagged and released at each location during round six (17-26 November) of the fall, 2004 fishing mortality study.

Tagging location	Year class	n	%	Mean FL (mm) YC	Mean FL (mm) total	Mean age
Chesapeake Bay (upper region)	2001	118	86.1	454.1	460.2	3.13
	2000	17	12.4	501.5		
	n/aged	2	1.5	472.0		
Chesapeake Bay (middle region)	2001	532	55.7	463.1	499.0	3.54
	2000	334	35.0	528.0		
	1999	62	6.5	603.3		
	1998	13	1.4	662.3		
	1997	1	0.1	720.0		
	1996	1	0.1	782.0		
	n/aged	12	1.3	521.9		
York River (middle section)	2001	51	92.7	447.3	456.7	3.09
	2000	3	5.5	557.0		
	1999	1	1.8	637.0		
James River (middle section)	2001	1	20.0	459.0	523.4	3.8
	2000	4	80.0	539.5		

Table 8. Number, location, mean fork length (FL in mm) and mean age of recaptured striped bass, by release location, 20 September - 31 December, 2004.

Release location	Chesapeake Bay (Va.) recaptures*								
		location						mean	
		river			Chesapeake Bay			FL	age
	total	Rap.	York	James	upper	middle	lower		
Rappahannock River	4	4	0	0	0	0	0	457.0	3.0
York River	59	0	56	0	0	0	3	508.1	3.7
James River	4	0	0	3	0	0	1	544.5	3.8
Chesapeake Bay (upper)	19	0	0	2	7	0	5	493.6	3.6
Chesapeake Bay (middle)	59	1	0	0	4	48	6	484.6	3.4

*Other recaptures	Tagging location	Recapture location
	York River	North Carolina
	Upper Chesapeake Bay	Chesapeake Bay-Maryland (3)
		Potomac River
		Atlantic Ocean-Virginia
	Middle Chesapeake Bay	Potomac River

Table 9. Summary of the disposition of striped bass tagged during round four (20-29 September) and subsequently recaptured prior to 31 December, with emphasis on the fourth recapture interval (25 September – 19 October, 2004).

Release location	recaptures								
	total	20 Sep - 24 Sep	25 Sep – 19 Oct						20 Oct - 31 Dec
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	4	0	0	0	0	0	2	0	2
York River	25	2	0	0	0	0	14	3	6
James River	0	0	0	0	0	0	0	0	0
Chesapeake Bay (upper)	6	0	0	0	0	0	4	0	2
Chesapeake Bay (middle)	43	12	0	0	0	2	20	0	9

R: released alive
H: harvested

Table 10. Summary of the disposition striped bass tagged during round five (18-27 October) and subsequently recaptured prior to 31 December 2004, with emphasis on the fifth recapture interval (20 October –18 November).

Release location	recaptures								
	total	18 Oct - 19 Oct	20 Oct – 18 Nov						19 Nov - 31 Dec
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	0	0	0	0	0	0	0	0	0
York River	30	0	0	0	1	1	19	0	9
James River	3	0	0	0	3	0	0	0	0
Chesapeake Bay (upper)	12	0	0	0	0	1	4	0	7
Chesapeake Bay (middle)	9	0	0	0	0	1	5	0	3

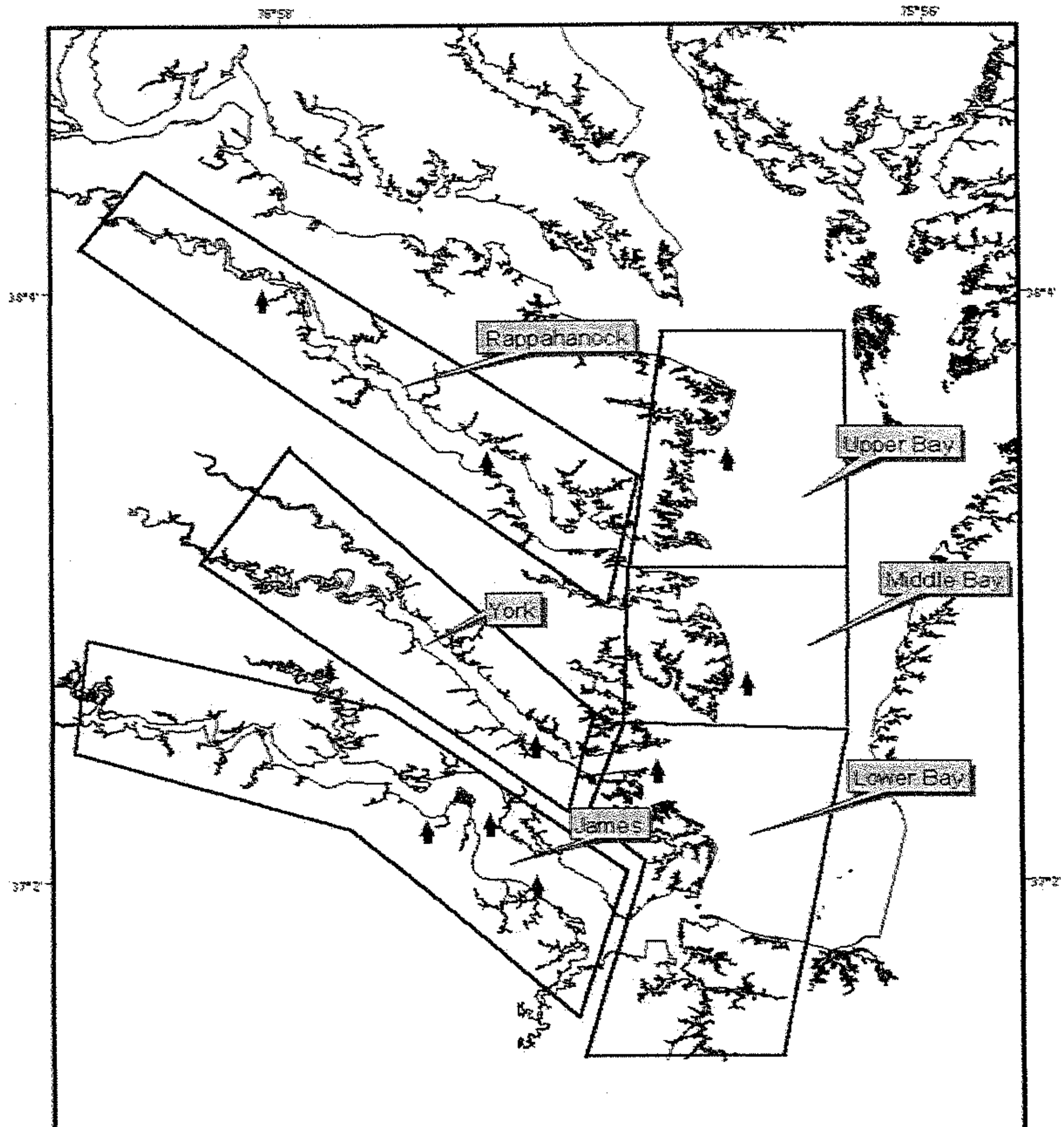
R: released alive
H: harvested

Table 11. Summary of the disposition of striped bass tagged during round six (17-25 November) and subsequently recaptured prior to 31 December, 2004.

Release location	recaptures								
			19 Nov - 31 Dec						
	total	17 Nov - 18 Nov	commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	0	0	0	0	0	0	0	0	
York River	4	0	0	0	1	1	2	0	
James River	1	0	0	0	1	0	0	0	
Chesapeake Bay (upper)	1	0	0	0	0	1	0	0	
Chesapeake Bay (middle)	7	0	0	0	1	0	6	0	

R: released alive
S: harvested

Figure 1. Delineation of western Chesapeake Bay, Virginia into tagging jurisdictions and location of tagging sites during fall, 2004.



IV. Striped bass spawning stock assessment in the Rappahannock River, Virginia: evaluation of the pound net-based Spawning Stock Biomass Index.

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Striped bass spawning stock assessment in the Rappahannock River, Virginia: evaluation of the pound net-based Spawning Stock Biomass Index.

Introduction

The Virginia Institute of Marine Science (VIMS) has produced abundance and biomass indexes of striped bass using pound nets and multi-mesh anchor gill nets since 1991. The 3 to 4 pound nets that are used to assess the spawning stock are located 6 to 10 river miles above the lower delineation of the striped bass spawning grounds near the brackish/freshwater interface. The gill nets are located 1 to 2 river miles upriver of the pound nets.

Pound nets are considered to be non-size or sex selective and striped bass of 200-1250 mm total length have been captured for our study. In contrast, the gill nets capture a much higher rate of smaller (<711 mm.) striped bass. These striped bass are mostly (> 90%) male. The local lore is that the fighting of gilled striped bass emulates spawning behavior ("rock fights") and attracts additional males. The gill nets under-represent the larger-sized, female-dominated striped bass (when compared to the pound net catches) which are the true basis of the spawning stock (Maryland DNR uses similar gear and has noted the same biases).

The pound nets are privately owned and operated. Although we have an excellent relationship with the fisherman, we do not have absolute control over how the nets are operated. Pound nets are fixed gear, which compromises their usefulness in calculating meaningful variances and other statistical measures that require random sampling. However, in analyzing these data over the years, we believe the results to be of considerable scientific value.

Methods

The three pound nets currently used for the index are located from river miles 45 to 47. A fourth net at river mile 44 was used from 1991-2000. The leaders originate in about three feet of depth and extend to the head in about 12 feet of water. The heads abut the channel and water depths drop rapidly to 30-40 feet.

The pound nets are generally fished on Mondays and Thursdays of each week and the entire catch of striped bass constitutes the sample. Thus the gear fishes continuously, usually for 72 or 96 hours. Deviations do occur, due to weather or fisherman constraints, though we try to minimize these events by sampling a net known to have been fished previously (to avoid gear saturation) or by returning the next day to collect the sample. The gill nets are also fished on Mondays and Thursdays and sample for 24 hours.

The samples are returned to VIMS for laboratory work-up. Each striped bass is measured (FL, TL in mm), weighed (g), its sex and gonadal stage recorded, and a scale sample taken. Since 2002, a sub-sample of the stripers sampled (including all specimens greater than 900 mm TL) also had their otoliths extracted. The scales of the striped bass are mounted and pressed on acetate sheets and an attempt is made to determine the age of all specimens. The spawning stock biomass index (SSBI) was defined (Sadler et al. 1998) as the mean CPUE (kg/day) of male (age 3+) and female (age 4+) striped bass captured between 30 March and 3 May of each year.

The striped bass scales are aged according to the protocol developed by Merriman (1941), except that scale impressions in acetate sheets have replaced scale specimens on glass slides and a microfiche reader has replaced a microscope. The index is then partitioned into age-specific components by CPUE (number of fish/day and kg/day).

Daily mean water flows for March, April and May from 1985 to 2003 were obtained from the United States Geological Service (USGS) and were measured at Fredricksburg. Although Fredricksburg is approximately 50 miles upriver of the sampling location, there are no additional significant freshwater inflows (other than local drainage) between the USGS station and our sampling location.

Results

A total of 7,426 striped bass have been sampled from the Rappahannock River pound nets since 1991 (Sadler *et al.* 2004). Annual totals varied from 151 (1992) to 1, 508 (2000) with a mean of 530.4 (Table 1). The resultant SSBIs (sexes combined) ranged from 18.5 (2002) to 123.9 (2004) with a mean of 52.9. In most years (11 out of 14), the contribution of female striped bass to the index exceeded that for the males. There was no temporal pattern to the index values, other than the two highest values for the females and for the males and females combined occurring in the past two years.

In addition to the biomass-based SSBI, age-specific CPUEs (number fish/day and kg/day) were tabulated (Table 2). These data are useful for demonstrating year class strengths and for estimates of annual survival (S). Striped bass appear fully recruited to the pound nets at age three, although the maximum CPUE is often age four or five due to the influx of first-spawning females. These temporal data also illustrate the increased contribution to the spawning stock of older (age 8+), and therefore larger and more fecund, striped bass during the time series.

These age data were also tabulated on a sex-specific basis (Tables 3 and 4). The cumulative CPUEs over all age classes for both sexes are highly variable and tend to be dominated by the recruitment of strong year classes to the pound nets. This is notable for the 1992, 1993, and especially for the 1996 year classes. These same year classes form the basis for the aforementioned dramatic increase in the abundance of older striped bass of both sexes in 2003 and 2004.

No estimates of variance are made. Since each sample consists of an entire catch from a pound net so there is no sampling variance. The use of fixed, therefore non-random, sampling gear within a restricted temporal window precludes calculating a seasonal variance as a useful measure of sampling adequacy.

Comparison of the temporal window with full seasonal data

The 30 March – 3 May temporal window for the Rappahannock River indexes was established in 1999 after evaluation of the data from 1993-1998 (Sadler *et al.* 1999). The dynamics for establishing the pound nets involve weather constraints (the threat of icing, flooding and dangerous debris conditions) and the market for the fish captured in the pound nets. The fishermen are also active in the gill net fishery that is allowed until 31 March each year. Hence, seasonal sampling of the pound nets began as early as 9 March in 1998 and as late as 7 April in 1994. The terminal end of the season was a combination of the fishermen inactivating their gear in favor of the lucrative blue crab peeler fishery that commences in May, the termination of our spring tagging program after water temperatures exceeded 22 degrees C (due to concerns of increased tagging mortality), and a typical rapid decline in the abundance of striped bass. Hence, the sampling ended as early as 21 April and as late as 3 May. We also evaluated catch data from multi-mesh anchored gill nets that were sampled between one to two miles upriver of the pound nets. The sampling season of the gill nets started as early as 6 March and extended as late as 7 May.

There was a definite trend in the temporal distribution of the catches of female striped bass from 1993-1998 (Figure 1). These catch rates were very low in March compared to the catch rates in April. This trend was not evident for the catches of male striped bass. Re-examining the temporal trends using all the presently available data (1991-2004) did not significantly change the original observations (Figure 2). The temporal trend in the catch rates of striped bass from the gill nets was similar to that from the pound nets.

There were additional differences in the catches of the pre-30 March samples compared to the 30 March – 3 May samples. Samples collected prior to 30 March were younger on average than those collected between 30 March and 3 May (Table 5). The age difference was greater for females than for males, reflecting the timing of the arrival of the larger and predominantly female migratory striped bass. The sex ratios were also different between the two temporal groupings. The 1995-1998 average ratio of males to females from samples prior to 30 March was 7.7:1, but was 3.2:1 from 30 March – 3 May. Thus, the description and assessment of the spawning stock would be greatly influenced by how early and how often samples were acquired in a given year. The restriction of the index to the 30 March – 3 May temporal window allowed for a better inter-annual assessment of the spawning stock.

Influence of river flow on the juvenile and spawning stock indexes

River flows from 1985-2003 (USGS 2004) were compared to the yearly spawning stock biomass indexes (SSBI) and juvenile indexes (JI). River flows could affect the catchability of striped bass by displacing the spawning grounds more upriver or downriver than in less extreme conditions, or by changing turbidity (the fishermen indicate that striped bass respond to rapid increases in turbidity by relocating downriver into clearer, more saline waters). River flows also affect the survival rate of the spawn and can influence year class strength.

No definitive relationship between river flow and the SSBI was apparent (Table 6). The values of the male and female components of the index varied independently through all flow regimes. In 1992 and 1996, both cooler and wetter than normal but not the most extreme flow conditions encountered, the local fishermen indicated that striped bass were spawning well below our sampling site. In both of these years, catches of striped bass in the pound nets were lower for all age classes relative to the previous or the ensuing years. In 2002, at the culmination of a nearly three-year drought, there was extreme short-term variation in air and water temperatures in mid-April (multiple days with air temperatures exceeding 30 °C, followed by sub-freezing temperatures and snow, followed by a second period of air temperatures exceeding 30 °C). Those striped bass present spawned (mostly partially spawned) and immediately left the area and few striped bass entered the area thereafter. The result was another year in which the CPUE of all age classes were lower than the previous or the ensuing years (and in this case a weak JI).

The strength of the spawning stock was not an indicator of the strength of that year's juvenile index (as would be expected since stock-recruitment relationships generally appear weak). However, years with high mean flows or high peak flows (eg. 1987 and 1993) had higher juvenile indexes while years with low mean and peak flows (eg. 1985, 1995 and 1999) had low juvenile indexes (Table 7).

Comparison of VIMS pound net index data with VIMS juvenile index data

Comparisons were made between the VIMS Rappahannock River juvenile index (JI, Austin *et al.* 2004) for a year and the age-specific CPUE of that year class over time (e.g., the 1990 JI with the age three CPUE in 1993, age four CPUE in 1994, etc.). Ideally the CPUEs of ages at which striped bass are fully recruited to the pound nets and at maximum abundance, ages five and six, would correlate with strong and weak year classes as predicted by their juvenile indexes. Unfortunately, plots of the CPUEs of three to five year-old striped bass poorly track their respective juvenile indexes (Figure 3), especially for the very strong indexes for 1992 and 1993 (the central peak in the graphs) and correlations of the juvenile indexes to these age classes were very weak (Figure 4).

The plots of the six to eight year-old striped bass also fail to track their respective juvenile indexes (Figure 5) and give similarly poor correlations (Figure 6). From 1997-2001 striped bass of 580-680 mm fork length were almost completely absent from the pound net (and gill net) samples. The reason for this extended absence is unclear, but cannot be explained by any single environmental factor. These striped bass are mostly six years of age, so again the predicted strong 1992 and 1993 year classes were not tracked well by these age classes from the pound net index during these years. The abundance of six to eight year-olds rapidly increased in the pound net samples after 2001, which corresponds to the predicted strong 1996 and 1997 year classes.

The plots of nine and ten year-old striped bass show a transition towards a closer tracking of their respective juvenile indexes (Figure 7). While the results of the previous age classes were dominated by resident, mostly male, striped bass, these nine and ten year-old striped bass were predominantly migrant female striped bass returning to the Rappahannock River to spawn. Abnormally low catches across all age classes in 2002 resulted in the failure of the nine year-olds to track the strong 1993 year class and the ten year-olds to track the strong 1992 year class. Hence, overall correlations of these two age classes with their respective juvenile indexes were still weak (Figure 8).

The plots of eleven and twelve year-old striped bass more closely paralleled the juvenile indexes (Figure 9). These age classes are almost entirely comprised of fully mature, migrant female striped bass returning to the Rappahannock River to spawn. Unlike any of the other age classes, there was a strong peak of abundance of the 1992 year class striped bass (in 2003 and 2004). Accordingly, the correlation of eleven and twelve year-old striped bass with their respective juvenile indexes was much higher (Figure 10) than in the younger age classes.

Comparison of the Rappahannock River and Virginia Juvenile Indexes

The juvenile indexes for the Rappahannock River generally tracked their corresponding Virginia juvenile indexes, but there were two major exceptions. In 1987 and 1992, the juvenile index indicated exceptionally strong year classes for the Rappahannock River, but only a moderately strong year class in 1987 and a below average year class in 1992 as indicated by the Virginia index (Figure 11). These two strong year classes have been large contributors to the Spawning Stock Biomass Index (the 1987 year class as four to six year-olds and the 1992 year class as 10-12 year-olds) and thus weaken any correlation to the Virginia juvenile index. It should be noted that the Rappahannock River contributed the least of the three river systems to the 1980-2004 Virginia juvenile index (York River 37.9%, James River 33.2%, Rappahannock River 28.9%).

Comparison of the Rappahannock River SSBI and the Maryland Juvenile Indexes

The 1987 and 1992 Maryland juvenile indexes (Durell and Weedom, 2003) were also weaker in relative magnitude than in the Rappahannock River (Table 8). In fact, there were no major peaks in the Maryland juvenile indexes from 1980-1992 (Figure 12). Thus, it would not be expected that the age-specific CPUEs from the Rappahannock River SSBI would correlate with the Maryland JI for the pre-1993 period. From 1993-2004, the juvenile indexes from all rivers in both jurisdictions of Chesapeake Bay have had repeated strong peaks in abundance, most notably in 1993, 1996 and 2003. Similarly the 2002 juvenile index was the lowest since 1993 throughout Chesapeake Bay. However, the low catches of all age classes in 1996 and 2002, coupled with the lack of 580-680 mm fork length striped bass previously described, preclude the Rappahannock SSBI from any relationship with the Maryland juvenile index.

Discussion

The use of the pound nets to describe the spawning stock in the Rappahannock River has several advantages. The pound nets are not size or sex-selective for mature striped bass. By sampling for (usually) 72 or 96 hours, much of the short-term changes in abundance that affect short-duration sampling (trawls, gill nets, electro-shocking, etc.) is smoothed out. In fact, these samples represent continuous sampling of the Rappahannock River spawning grounds for the duration of the sampling season. It also provides a better representation of the larger, older striped bass than the multi-mesh experimental gill nets used to describe the same spawning stock. These older striped bass have increased in prevalence in recent years and, because of their much higher fecundity, have come to dominate both biomass and egg potential-based indexes.

However, because the pound nets are fixed sampling gears, no estimate of variability is possible. There is also the increased likelihood of unmeasurable changes in catchability due to changes in conditions within the spawning zone in response to environmental extremes. Presumedly, the poor catches of all size and age classes that occurred in 1992, 1996 and 2002 were the results of extreme environmental conditions, since these same age classes rebounded the next year (resulting in implausible survival estimates for that year).

It is not clear why there were so few 580-680 mm fork length striped bass caught from 1997-2001. These fish were captured in increasing numbers from 1991-1996 as the large 1987-1989 year classes matured. Although the 1990 and 1991 year classes were much weaker, the very large 1992 and 1993 year classes were missed as they grew through this size range. These two large year classes have been documented as having above-average CPUEs as 11 and 12 year-olds (by both scale and otolith ageing), which validate the high juvenile indexes reported for 1992 and 1993. This size class has increased in abundance since 2001, as the very large 1996 and 1997 year classes matured through this size range.

The below-expected catches in 1992, 1996 and 2002 and the "missing" mid-size striped bass in 1997-2001 make it impossible to correlate the SSBI with the juvenile index and greatly complicate estimating annual survival rates. Environmental extremes and changes in catchability occur periodically and adversely affect most field sampling programs. The correlations of the CPUE of every age class with their respective JI, except one, was positive, suggesting that some relationship exists. At present, only 11 and 12 year-old striped bass show any promise for validating the juvenile index. However, if the 1997-2001 lack of mid-size striped bass is not a recurring phenomenon, then five and six year-old striped bass should begin increasingly correlating with their respective juvenile indexes.

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Table 1. Values of the VIMS Rappahannock River pound net Spawning Stock Biomass Index, 1991-2004.

Year	number of fish	% males	SSBI (kg/day) males	SSBI (kg/day) females	SSBI (kg/day) combined
1991	223	68.6	21.3	21.5	43.8
1992	151	33.8	5.4	19.4	24.8
1993	565	66.7	31.2	37.5	68.7
1994	375	62.4	17.1	30.9	48
1995	363	79.1	12.4	19.8	32.2
1996	430	83	14.1	9.3	23.4
1997	406	71.3	22.2	49.6	71.7
1998	401	71.8	14.8	36.4	51.2
1999	836	92.7	30.5	19.8	50.3
2000	1,508	95	42.7	14.6	57.3
2001	577	81.2	24.2	27.6	51.8
2002	170	67.6	7.1	11.4	18.5
2003	470	67.4	22.8	53.6	76.4
2004	951	74	58.5	65.4	123.9
mean	**530.4**	**72.5**	**23.2**	**29.8**	**52.9**

Table 2. Age-specific CPUE, sexes combined, from the VIMS Rappahannock River pound net spawning stock assessment survey, 30 March – 3 May, 1991-2004 (maximum values in bold).

	CPUE (fish/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.42	0.2	0.12	0	0.04	0	0	0	0	0	0	0	0	0
2	0.33	0.5	0.58	1.44	3.04	0.51	0.6	0.19	0.79	0.03	0.06	0	0	0.03
3	3.58	0.6	1.04	0.48	**4.8**	**3.97**	3.9	2.15	**11.54**	15.61	2.74	0.5	0.77	3.47
4	**8**	1.6	3.58	1.33	1	2.86	**8.1**	**6.33**	**11.5**	**18.13**	**7.48**	**1.44**	3	5.57
5	3.67	**2.75**	**9.54**	**4.59**	2.24	1.63	1.25	1.48	2.79	3.34	4.29	1.38	**3.33**	**5.9**
6	1.67	1.15	3.65	2.22	0.68	1.26	0.05	0.04	0.11	0.11	0.1	0.25	0.37	3.53
7	0.5	0.3	0.65	1.15	0.6	0.89	0.7	0.52	0.5	0.5	0.58	0.78	1.83	2.23
8	0.25	0.4	0.42	0.59	0.68	0.37	0.8	0.7	0.43	0.5	0.87	0.41	1.4	4.17
9	0.17	0.2	0.58	0.52	0.4	0.37	1.5	0.78	0.32	0.39	0.87	0.28	1.7	2.33
10	0.5	0.3	0.46	0.33	0.08	0.09	1	0.89	0.36	0.29	0.81	0.19	1.43	1.67
11	0.08	0.15	0.31	0.33	0.28	0	1	0.89	0.39	0.37	0.45	0.06	1.13	1
12			0.27	0.19	0.08	0	0.35	0.22	0.43	0.05	0.26	0	0.33	1.1
13			0.15	0.07		0.03	0.35	0.15	0.04	0.05	0.1	0	0.27	0.17
14				0.04			0.2	0.07	0.11			0	0.07	0.07
15				0.04					0.04			0.03	0	0.07
16													0.03	
no age	0.58	0.3	0.38	0.56	0.6	0.31	0.5	0.44	0.54	0.32	0	0	0	0.4
Sum	19.75	8.45	21.73	13.88	14.52	12.29	20.3	14.85	29.89	39.69	18.61	5.32	15.66	31.71

	CPUE (kg/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.08	0.03	0.02	0	0	0	0	0	0	0	0	0	0	0
2	0.15	0.24	0.2	0.36	1.12	0.19	0.22	0.06	0.25	0.01	0.03	0	0	0.01
3	3.88	0.59	1.09	0.41	3.85	2.81	3.25	1.55	8.1	12.24	2.15	0.47	0.55	2.61
4	**13.41**	2.78	6.12	2.2	1.6	3.37	10.45	8.1	**14**	**21.02**	**8.84**	2.01	3.51	7.21
5	8.69	**6.85**	**22.99**	**10.72**	**5.69**	3.41	2.26	2.51	5.13	6.28	8.21	2.96	6.03	11.55
6	5.56	3.81	13.41	7.83	2.72	**3.64**	0.18	0.1	0.38	0.36	0.33	0.83	1.15	9.7
7	2.25	1.34	3.48	6.33	3.43	**3.67**	3.34	2.57	2.4	2.65	2.76	**3.94**	8.53	10.15
8	1.58	2.46	3.11	4.36	4.99	2.17	4.63	4.46	2.66	3.29	5.85	2.72	8.59	**23.63**
9	1.29	1.69	4.52	4.23	3.49	2.6	**11.83**	6.02	2.61	3.25	6.82	2.2	**13.15**	16.06
10	4.54	2.83	4.35	3.26	0.91	0.62	9.3	8.22	3.25	2.81	7.35	2.01	**13.19**	14.71
11	0.81	1.67	3.27	3.47	3.39	0	11.12	**10.08**	4.13	3.76	4.92	0.74	12.02	10.32
12			3.3	2.41	0.82	0	4.72	2.94	4.95	0.6	3.15	0	3.93	12.66
13			1.78	0.97		0.49	4.81	2	0.53	0.66	1.4	0	3.99	2.44
14				0.75			2.96	1.31	1.52			0	1	1.08
15				0.62					0.64			0.62	0	1.08
16													0.67	
no age	1.43	0.98	1.27	2.18	1.44	0.67	2.98	1.3	0.63	0.35	0	0	0	0.79
Sum	43.67	25.27	68.91	50.1	33.45	23.64	72.05	51.22	51.18	57.28	51.81	18.5	76.31	124

Table 3. Age-specific CPUE, males only, from the VIMS Rappahannock River pound net spawning stock assessment survey, 30 March – 3 May, 1991-2004 (maximum values in bold).

	CPUE (fish/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.17	0.1	0.12	0	0.04	0	0	0	0	0	0	0	0	0
2	0.17	0.35	0.54	1.22	2.88	0.51	0.55	0.19	0.79	0.03	0.06	0	0	0.03
3	3.25	0.4	0.96	0.48	**4.68**	**3.83**	3.8	2.15	**11.54**	15.61	2.74	0.44	0.77	3.47
4	**6.08**	**0.9**	3.46	1.3	0.92	2.66	**7.5**	**6.19**	**11.46**	**18.11**	**7.42**	**1.38**	2.93	5.47
5	2.58	0.65	**7.54**	**3.52**	2	1.34	1.15	1.37	2.68	3.21	4.03	1.25	**3.07**	**5.67**
6	0.5	0.3	1.23	1.11	0.08	0.94	0.05	0	0.07	0.08	0.1	0.25	0.3	3.37
7	0.08	0.05	0.15	0.22	0.12	0.43	0.35	0.3	0.36	0.26	0.39	0.16	1.5	1.93
8		0.15	0.04	0.11	0	0.03	0.55	0.11	0.21	0.11	0.16	0.03	0.57	2.23
9			0.08	0.04	0.04	0.09	0.2	0.04	0	0.05	0.19	0.03	0.23	0.53
10				0					0.04	0.03	0.13		0.07	0.2
11				0						0.03				0.1
12				0.04										0.07
13														
14														
15														
16														
no age	0.25	0.1	0.27	0.41	0.44	0.23	0.25	0.33	0.54	0.32	0	0	0	0.4
Sum	13.08	3	14.39	8.45	11.2	10.06	14.4	10.68	27.69	37.84	15.22	3.54	9.44	23.47

	CPUE (kg/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.03	0.02	0.02	0	0	0	0	0	0	0	0	0	0	0
2	0.09	0.18	0.19	0.32	1.07	0.19	0.2	0.06	0.25	0.01	0.03	0	0	0.01
3	3.54	0.38	1.01	0.41	3.72	2.71	3.15	1.55	8.1	12.24	2.15	0.4	0.55	2.61
4	**9.71**	**1.42**	5.9	2.14	1.49	**3.06**	**9.48**	**7.84**	**13.94**	**20.99**	**8.74**	1.94	3.44	7.07
5	5.95	**1.43**	**17.71**	**7.77**	**5.01**	2.75	2.07	2.31	4.92	6.02	7.63	**2.67**	5.55	11.06
6	1.46	0.87	4.25	3.43	0.33	2.68	0.18	0	0.26	0.25	0.33	0.83	0.95	9.25
7	0.31	0.24	0.83	1.14	0.65	1.76	1.63	1.57	1.68	1.35	1.81	0.8	**6.89**	8.78
8		0.84	0.27	0.73	0	0.17	3.15	0.68	1.29	0.6	1	0.19	3.3	**12.22**
9			0.65	0.33	0.35	0.65	1.49	0.26	0	0.4	1.39	0.26	1.51	3.38
10				0					0.3	0.21	1.13		0.58	1.63
11				0						0.27				1.05
12				0.51										0.7
13														
14														
15														
16														
no age	0.37	0.26	0.6	1.22	0.85	0.32	1.02	0.6	0.63	0.35	0	0	0	0.79
Sum	21.46	5.64	31.43	18	13.47	14.29	22.37	14.87	31.37	42.69	24.21	7.09	22.77	58.55

Table 4. Age-specific CPUE, females only, from the VIMS Rappahannock River pound net spawning stock assessment survey, 30 March – 3 May 1991-2004 (maximum values in bold).

	CPUE (fish/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.25	0.1	0	0	0	0	0	0	0	0	0	0	0	0
2	0.17	0.15	0.04	0.22	0.16	0	0.05	0	0	0	0	0	0	0
3	0.33	0.2	0.08	0	0.12	0.14	0.1	0	0	0	0	0.06	0	0
4	**1.92**	0.7	0.12	0.04	0.08	0.2	0.6	0.15	0.04	0.03	0.06	0.06	0.07	0.1
5	1.08	**2.1**	2	1.07	0.24	0.29	0.1	0.11	0.11	0.13	0.26	0.13	0.27	0.23
6	1.17	0.85	**2.42**	**1.11**	0.6	0.31	0	0.04	0.04	0.03	0	0	0.07	0.17
7	0.42	0.25	0.5	0.93	0.48	**0.46**	0.35	0.22	0.14	0.24	0.19	**0.63**	0.33	0.3
8	0.25	0.25	0.39	0.48	**0.68**	0.34	0.25	0.59	0.21	**0.4**	**0.71**	0.38	0.83	**1.93**
9	0.17	0.2	0.5	0.48	0.36	0.29	**1.3**	0.74	0.32	0.34	0.68	0.25	**1.47**	1.8
10	0.5	0.3	0.46	0.33	0.08	0.09	1	**0.89**	0.32	0.26	0.68	0.19	1.37	1.47
11	0.08	0.15	0.31	0.33	0.28	0	1	**0.89**	0.39	0.34	0.45	0.06	1.13	0.9
12			0.27	0.15	0.08	0	0.35	0.22	**0.43**	0.05	0.26	0	0.33	1.03
13			0.15	0.07		0.03	0.35	0.15	0.04	0.05	0.1	0	0.27	0.17
14				0.04			0.2	0.07	0.11			0	0.07	0.07
15				0.04					0.04			0.03	0	0.07
16													0.03	
no age	0.33	0.2	0.12	0.15	0.16	0.09	0.25	0.11	0	0	0	0	0	0
Sum	6.67	5.45	7.36	5.44	3.32	2.24	5.9	4.18	2.19	1.87	3.39	1.79	6.24	8.24

	CPUE (kg/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.05	0.01	0	0	0	0	0	0	0	0	0	0	0	0
2	0.07	0.07	0.01	0.04	0.05	0	0.02	0	0	0	0	0	0	0
3	0.34	0.21	0.08	0	0.13	0.1	0.1	0	0	0	0	0.06	0	0
4	3.7	1.37	0.22	0.06	0.11	0.3	0.97	0.26	0.07	0.03	0.1	0.08	0.07	0.14
5	2.74	**5.42**	5.28	2.95	0.68	0.66	0.2	0.2	0.21	0.26	0.58	0.29	0.48	0.49
6	4.09	2.94	**9.16**	4.4	2.39	0.96	0	0.1	0.12	0.11	0	0	0.21	0.45
7	1.94	1.09	2.65	**5.19**	2.78	1.9	1.72	1	0.72	1.31	0.96	**3.14**	1.64	1.37
8	1.58	1.62	2.84	3.63	**4.99**	**2.01**	1.48	3.78	1.37	2.68	4.85	2.54	5.3	11.41
9	1.29	1.69	3.87	3.89	3.14	1.95	10.33	5.75	2.61	2.85	5.43	1.94	11.64	12.68
10	**4.54**	2.83	4.35	3.26	0.91	0.62	9.3	8.22	2.96	2.6	**6.22**	2.01	**12.61**	**13.07**
11	0.81	1.67	3.27	3.47	3.39	0	**11.12**	**10.08**	4.13	**3.5**	4.92	0.74	12.02	9.28
12			3.3	1.91	0.82	0	4.72	2.94	**4.95**	0.6	3.15	0	3.93	11.95
13			1.78	0.97		0.49	4.81	2	0.53	0.66	1.4	0	3.99	2.44
14				0.75			2.96	1.31	1.52			0	1	1.08
15				0.62					0.64			0.62	0	1.08
16													0.67	
no age	1.06	0.72	0.67	0.96	0.58	0.35	1.96	0.71	0	0	0	0	0	0
Sum	22.21	19.64	37.48	32.1	19.97	9.34	49.69	36.35	19.83	14.6	27.61	11.42	53.56	65.44

Table 5. Comparison of catches and mean ages, by sex, of striped bass prior to and within the 30 March – 3 May temporal window, 1993-1998.

	pre-30 March				30 March - 3 May			
	Males		Females		Males		Females	
Year	N	$\overline{Age}$	N	$\overline{Age}$	N	$\overline{Age}$	N	$\overline{Age}$
1993	0		0		372	4.7	191	6.9
1994	0		0		228	4.5	147	7.2
1995	356	3.1	108	5.3	280	3.3	83	7.2
1996	103	3.3	14	6.6	353	4	78	6.8
1997	232	3.7	15	7.6	297	4.1	118	9.2
1998	410	3.5	6	6.5	288	4	101	9.5
95-98	1101	3.4	143	5.7	1218	3.9	380	8.4

Table 6. Comparison of river flows with Spawning Stock Biomass Indexes from pound nets in the Rappahannock River, 30 March – 3 May, 1985-2003 (Red denotes minimum values and blue denotes maximum values).

Year	River flows cf/s/day Mean	River flows cf/s/day Maximum	VIMS SSBI (pound nets) male	VIMS SSBI (pound nets) female	VIMS SSBI (pound nets) combined
1985	837	1320			
1986	1450	4290			
1987	4077	30100			
1988	1035	2450			
1989	1537	9610			
1990	2323	5790			
1991	1974	7970	21.3	21.5	42.8
1992	2216	16700	5.4	19.4	24.8
1993	4999	18100	31.2	37.5	68.7
1994	2923	15800	17.1	30.9	48
1995	829	1440	12.4	19.8	32.2
1996	2981	10500	14.1	9.3	23.4
1997	1835	3700	22.2	49.6	71.7
1998	2827	9490	14.8	36.4	51.2
1999	835	1130	30.5	19.8	50.3
2000	1845	4140	42.7	14.6	57.3
2001	2501	16000	24.2	27.6	51.8
2002	1190	4509	7.1	11.4	18.5
2003	3451	8547	22.8	53.6	76.4
2004			58.5	65.4	123.9
mean	2184	4227	23.2	29.8	52.9

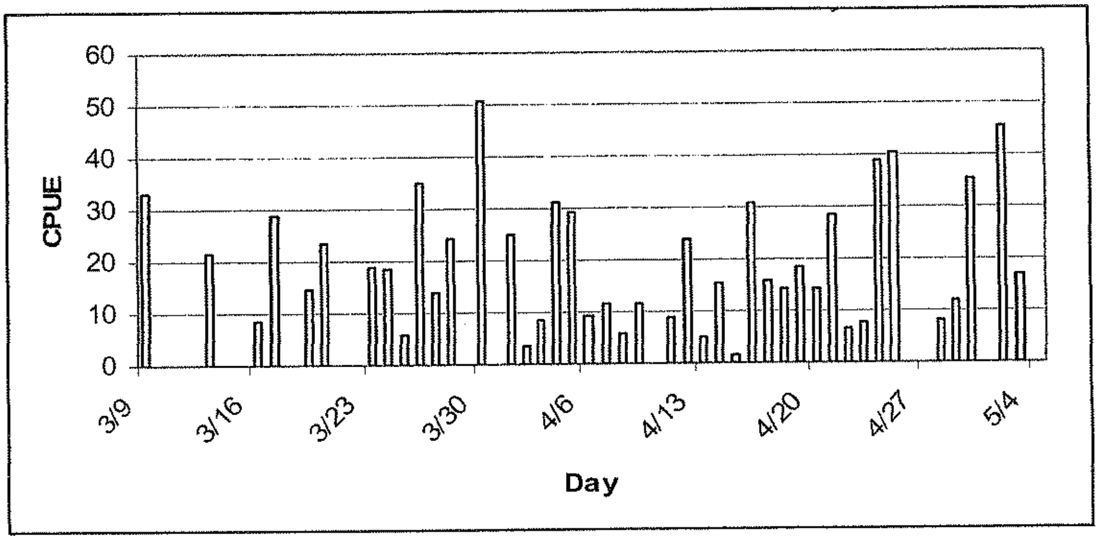
Table 7. Comparison of Rappahannock River flows (30 March – 3 May) with VIMS striped bass juvenile indexes, 1985-2004 (red denotes minimum values and blue denotes maximum values).

VIMS striped bass juvenile indexes					River flow (cf/s)	
Year	James	York	Rappahannock	Combined	Mean	Maximum
1980	4.77	2.51	0.75	2.54		
1981	1.2	2.42	0.88	1.57		
1982	2.71	3.28	1.98	2.71		
1983	4.43	2.63	3.77	3.48		
1984	5.59	4.8	2.57	4.36		
1985	2.94	3.42	0.8	2.41	837	1320
1986	8.63	2.67	4.49	4.75	1450	4290
1987	18.8	7.29	34.03	15.75	4077	30100
1988	6.8	5.06	14.55	7.64	1035	2450
1989	15.4	9.29	9.87	11.23	1537	9610
1990	12.21	6.72	4.18	7.64	2323	5790
1991	4.5	3.37	3.56	3.78	1974	7970
1992	3.71	3.64	30.92	7.32	2216	16700
1993	23.7	13.7	18.1	18.12	4999	18100
1994	10.28	11.29	9.7	10.49	2923	15800
1995	8.8	6.31	2.41	5.45	829	1440
1996	42.62	15.78	18.18	23.05	2981	10500
1997	9.22	6.49	9.52	8.24	1835	3700
1998	16.02	10.84	14.18	13.33	2827	9490
1999	5.33	0.64	4.55	2.8	835	1130
2000	26.64	11.88	13.32	16.18	1845	4140
2001	24.03	8.52	14.6	14.17	2501	16000
2002	9.97	0.9	4.96	3.98	1190	4509
2003	34.55	17.47	19.98	22.85	3451	8547
2004	12.13	11.5	15.36	12.7		
overall	9.23	5.64	7.35	7.21	2184	4227

Table 8. Comparison of the Virginia and Maryland juvenile indexes, by river, 1980-2004 (blue denotes maximum values and red denotes minimum values).

	VIMS striped bass juvenile indexes				Maryland striped bass juvenile indexes					
Year	James	York	Rap.	Mean	Chop.	Bay head	Nanti.	Poto.	Patux.	Mean
1980	4.77	2.51	0.75	2.54	0.60	1.43	0.81	1.04		1.02
1981	1.2	2.42	0.88	1.57	0.84	0.17	1.16	0.68		0.59
1982	2.71	3.28	1.98	2.71	5.68	2.98	3.08	3.50		3.57
1983	4.43	2.63	3.77	3.48	0.64	0.61	0.59	0.62	0.04	0.61
1984	5.59	4.8	2.57	4.36	2.13	2.24	0.81	1.42	0.39	1.64
1985	2.94	3.42	0.8	2.41	1.78	0.19	0.94	1.45	1.95	0.91
1986	8.63	2.67	4.49	4.75	0.32	0.90	1.24	3.09	1.17	1.34
1987	18.8	7.29	34.03	15.75	3.06	0.16	1.36	3.01	0.94	1.46
1988	6.8	5.06	14.55	7.64	0.40	2.25	0.28	0.22	0.40	0.73
1989	15.4	9.29	9.87	11.23	28.10	8.54	1.94	1.15	0.92	4.87
1990	12.21	6.72	4.18	7.64	1.34	2.20	0.56	0.38	0.17	1.03
1991	4.5	3.37	3.56	3.78	4.42	1.99	0.52	0.84	0.53	1.52
1992	3.71	3.64	30.92	7.32	2.07	0.87	1.72	6.00	1.85	2.34
1993	23.7	13.7	18.1	18.12	27.87	15.00	4.56	15.96	47.18	13.97
1994	10.28	11.29	9.7	10.49	7.71	12.88	9.06	2.01	2.82	6.40
1995	8.8	6.31	2.41	5.45	9.96	2.85	3.76	4.48	3.46	4.41
1996	42.62	15.78	18.18	23.05	33.29	15.00	19.13	13.60	58.11	17.61
1997	9.22	6.49	9.52	8.24	3.95	6.15	1.74	3.67	2.72	3.91
1998	16.02	10.84	14.18	13.33	21.10	4.32	2.74	4.42	7.58	5.50
1999	5.33	0.64	4.55	2.8	20.01	1.91	5.52	5.84	5.39	5.34
2000	26.64	11.88	13.32	16.18	12.53	8.84	10.86	3.52	5.03	7.42
2001	24.03	8.52	14.6	14.17	86.71	7.15	20.31	5.01	10.01	12.57
2002	9.97	0.9	4.96	3.98	0.38	1.35	4.89	3.95	0.69	2.20
2003	34.55	17.47	19.98	22.85	20.56	11.89	3.25	12.81	22.17	10.83
2004	12.13	11.5	15.36	12.7	9.52	4.17	9.65	2.36	1.29	4.85
overall	9.23	5.64	7.35	7.21						

Figure 1. Temporal distribution of male (top graph) and female (bottom graph) striped bass catches (kg/day) from pound nets in the Rappahannock River, 1993-1998.



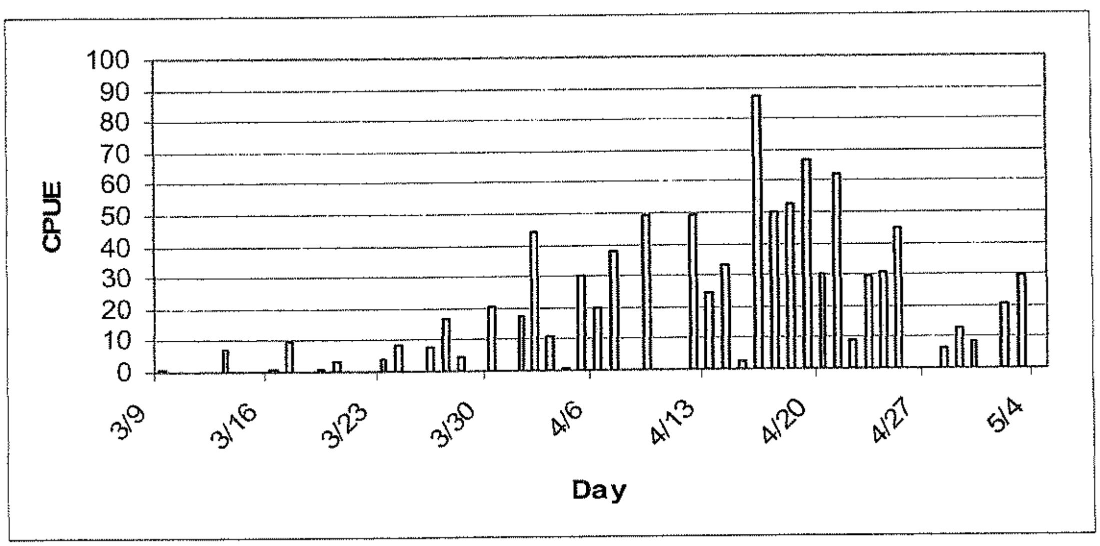
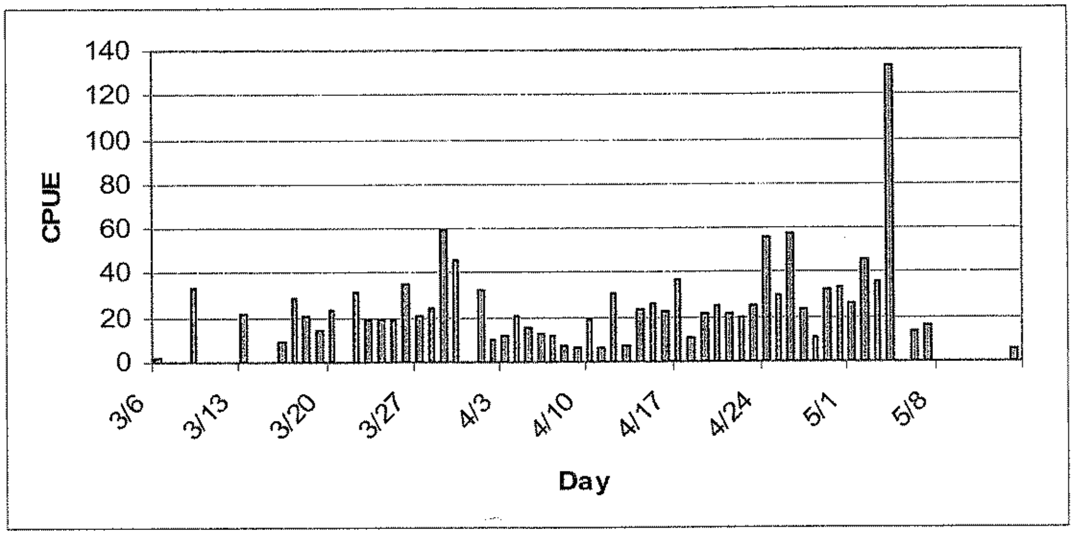


Figure 2. Temporal distribution of male (top graph) and female (bottom graph) striped bass catches (kg/day) from pound nets in the Rappahannock River, 1991-2004.



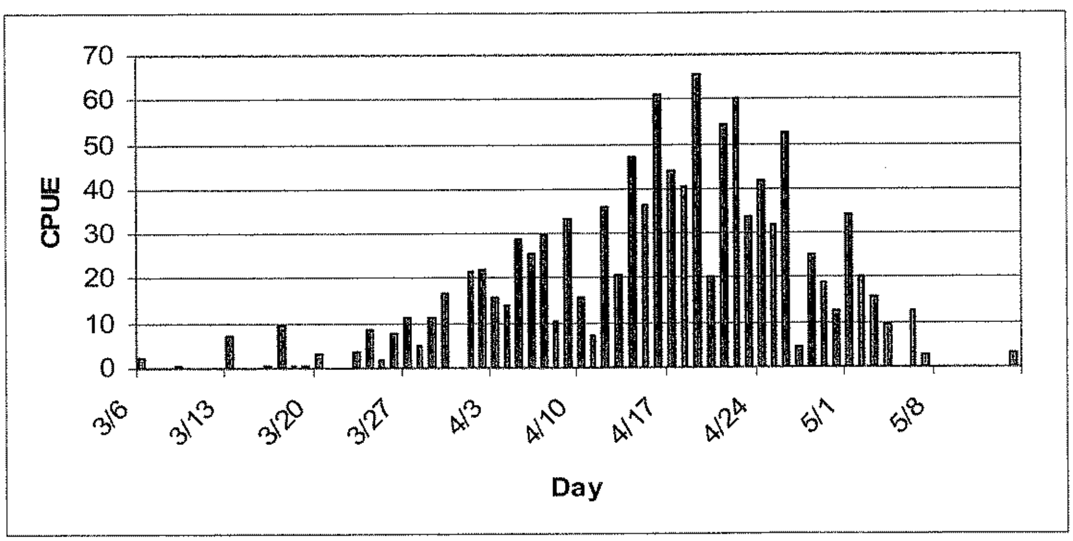
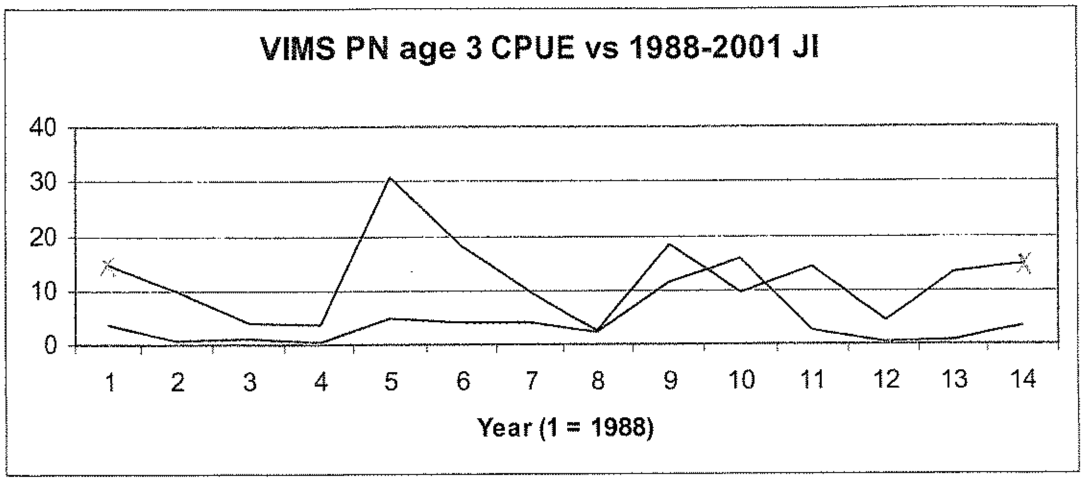
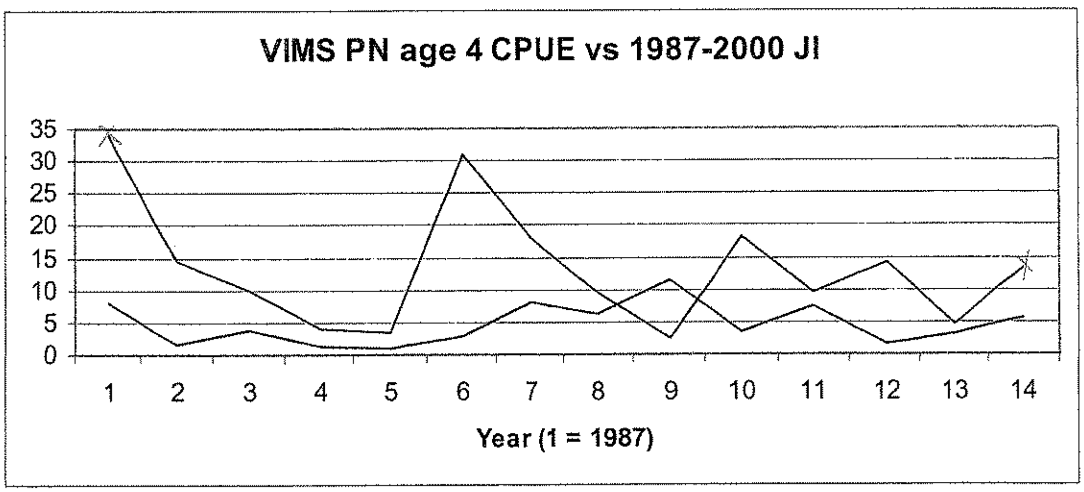


Figure 3. Comparison of the VIMS Rappahannock River juvenile indexes (red lines) with their respective age-three through age-five CPUEs (blue lines) of striped bass from the pound net index.





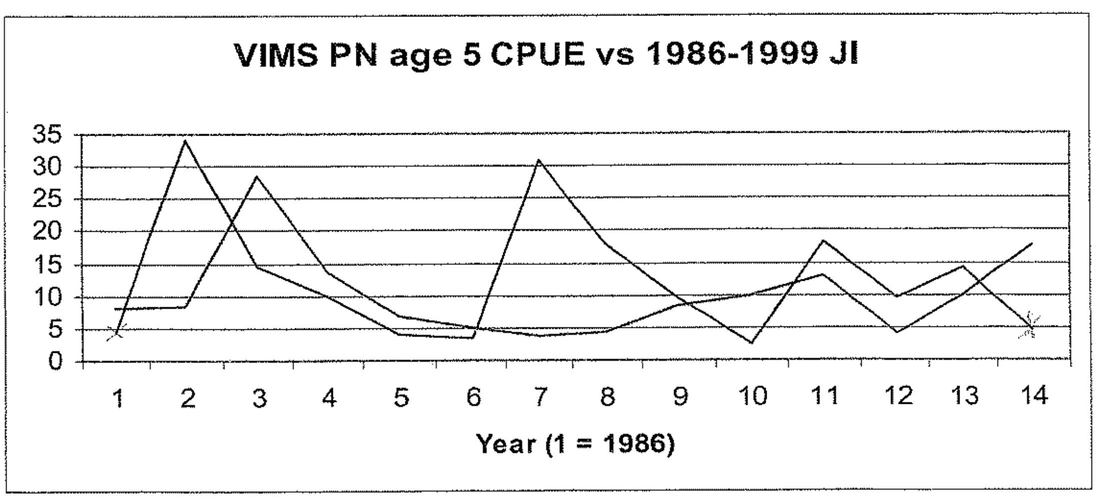
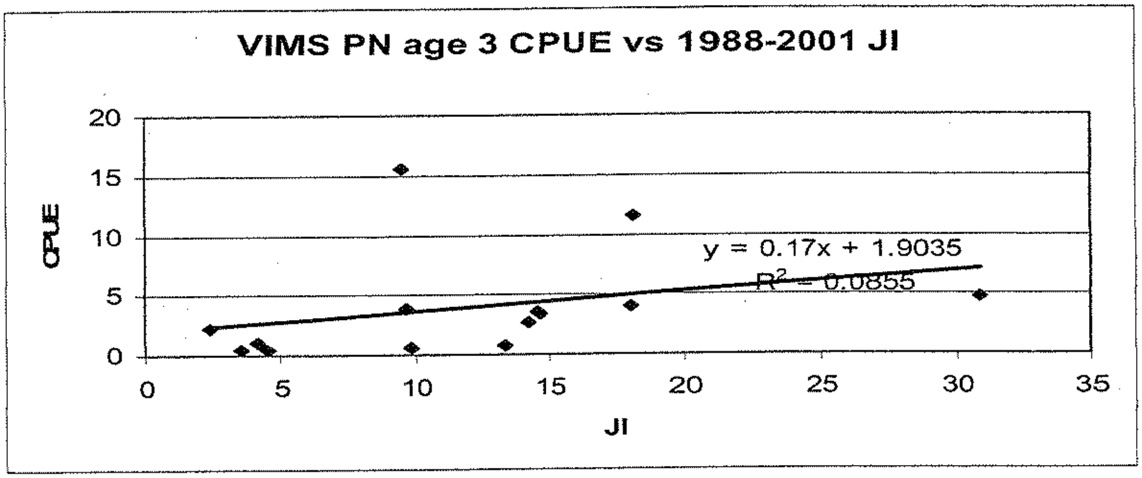
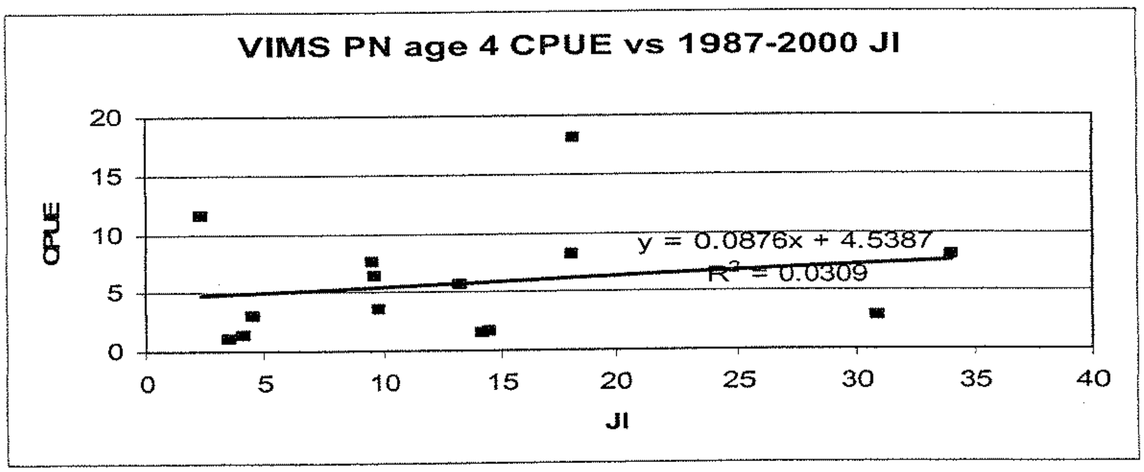


Figure 4. Correlation of the VIMS Rappahannock River juvenile indexes with their respective age-three through age-five CPUEs of striped bass from the pound net index.





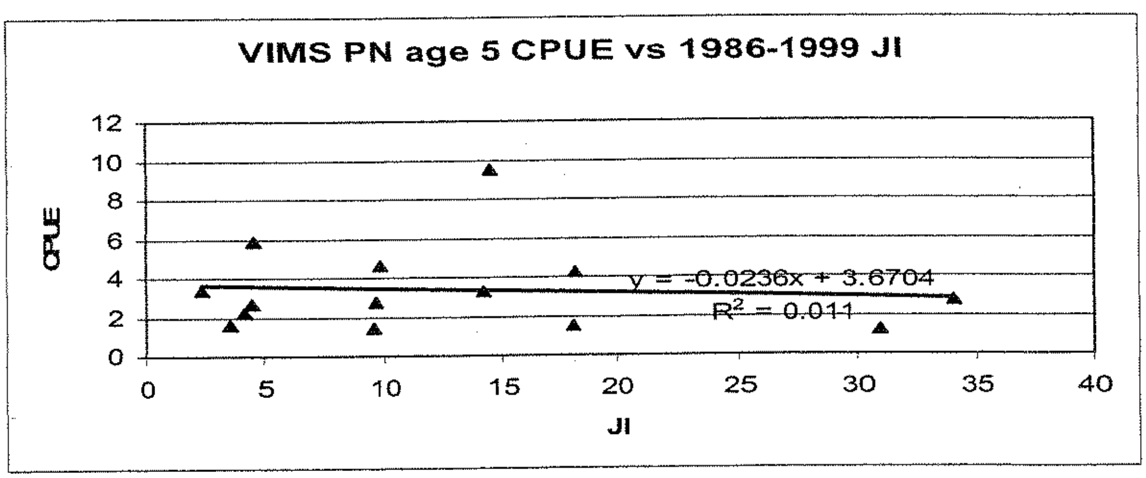
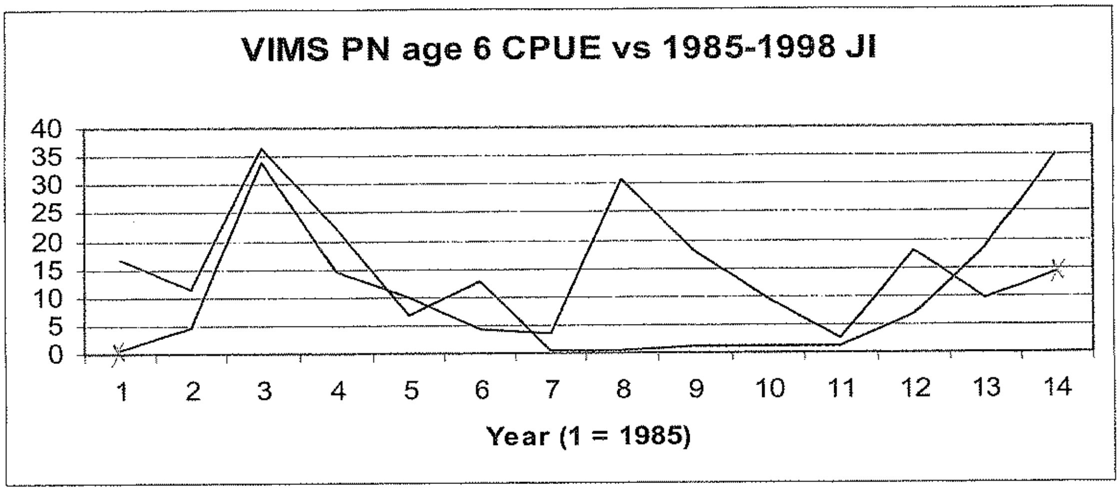
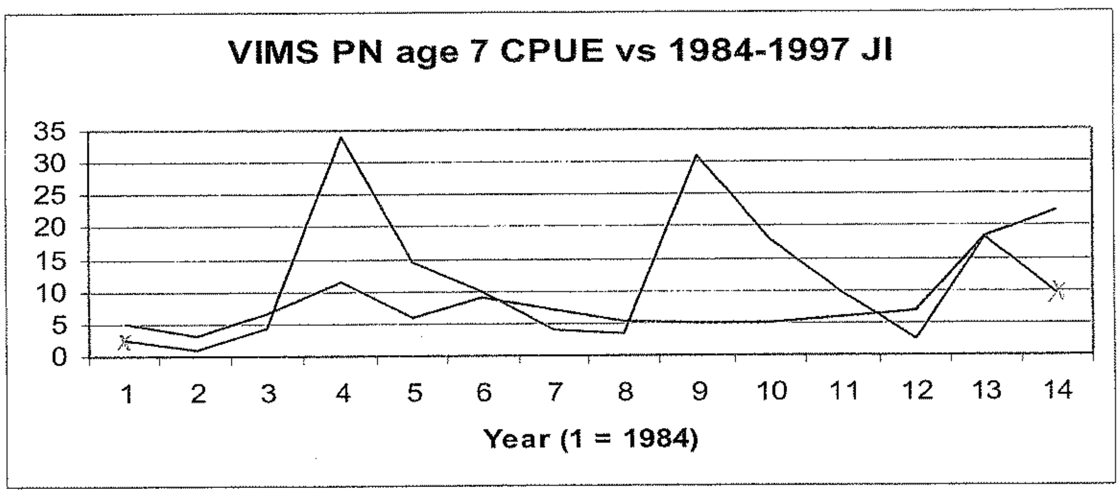


Figure 5. Comparison of the VIMS Rappahannock River juvenile indexes (red lines)× with their respective age-six through age-eight CPUEs (blue lines) of striped bass from the pound net index.





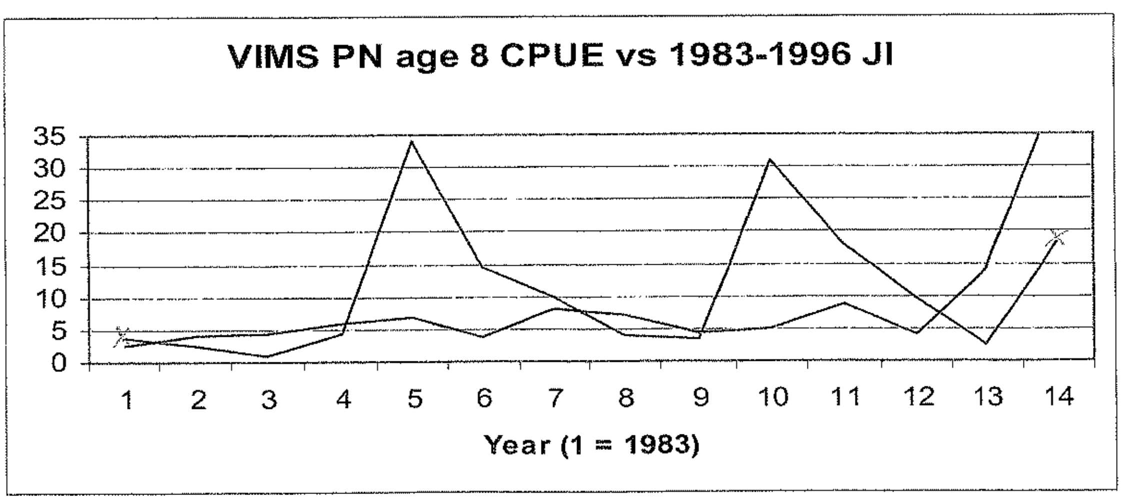
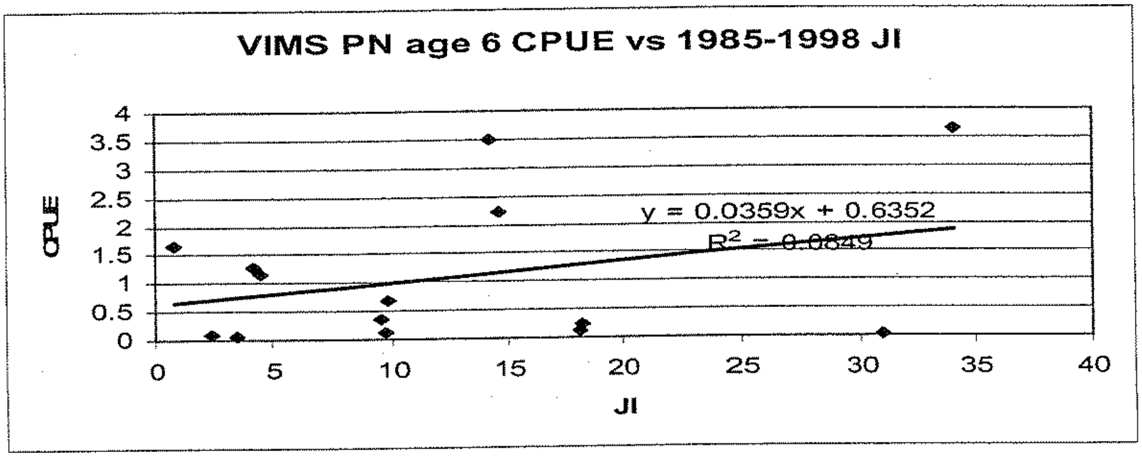
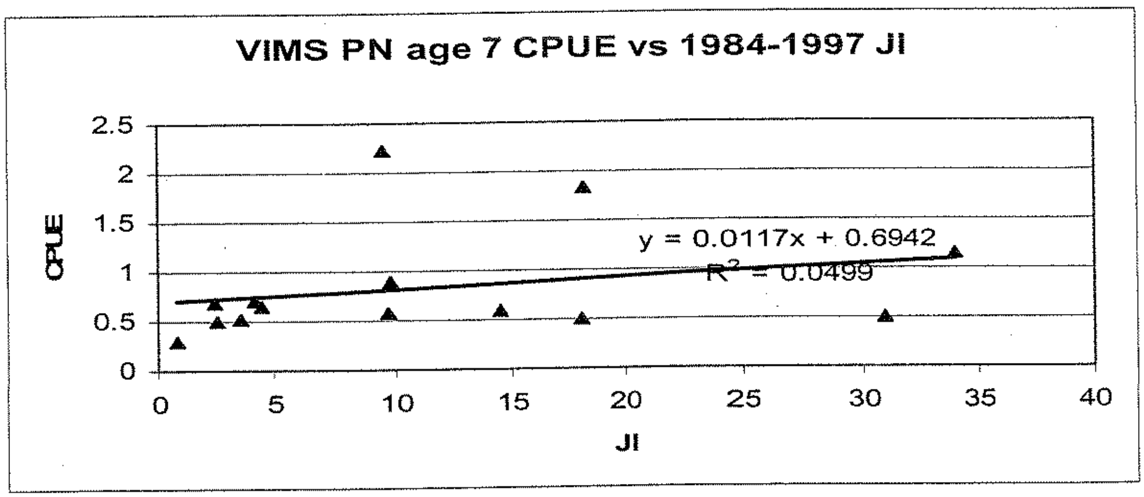


Figure 6. Correlation of the VIMS Rappahannock River juvenile indexes with their respective age-six through age-eight CPUEs of striped bass from the pound net index.





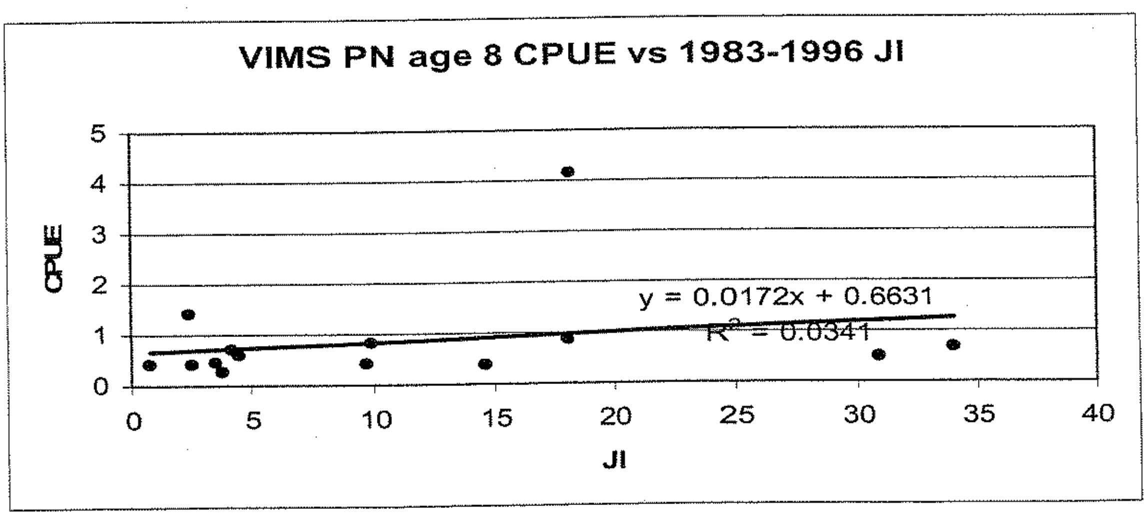
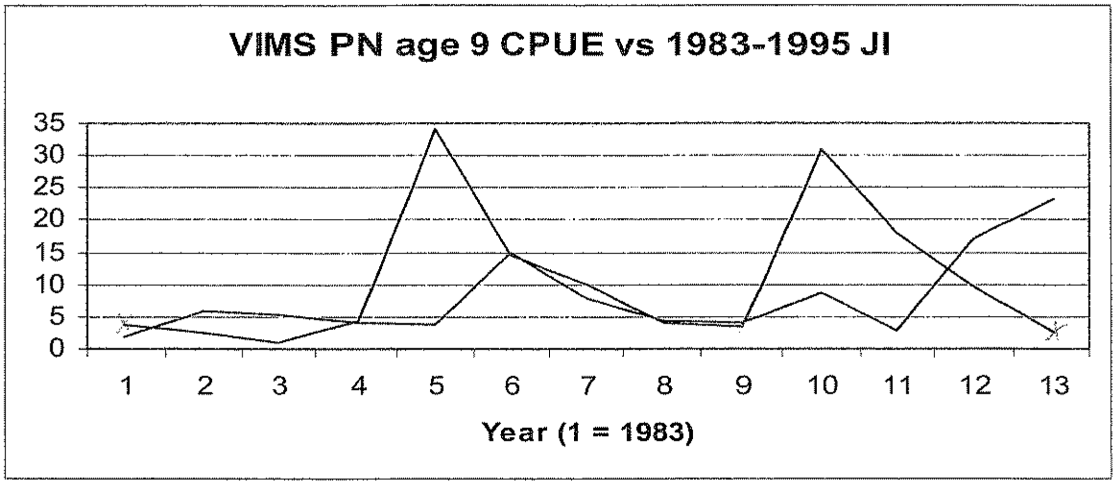


Figure 7. Comparison of the VIMS Rappahannock River juvenile indexes (red lines) with their respective age-nine and age-ten CPUEs (blue lines) of striped bass from the pound net index.



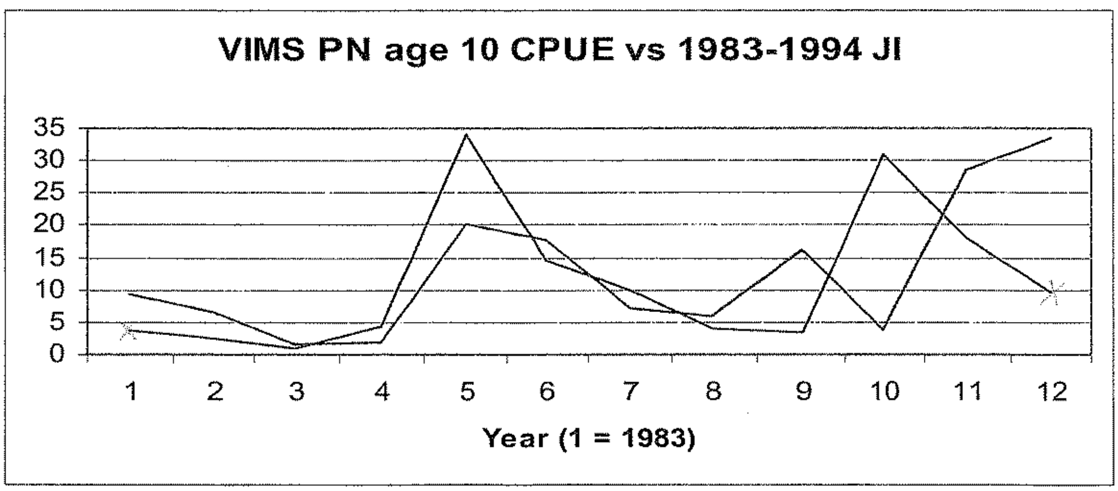
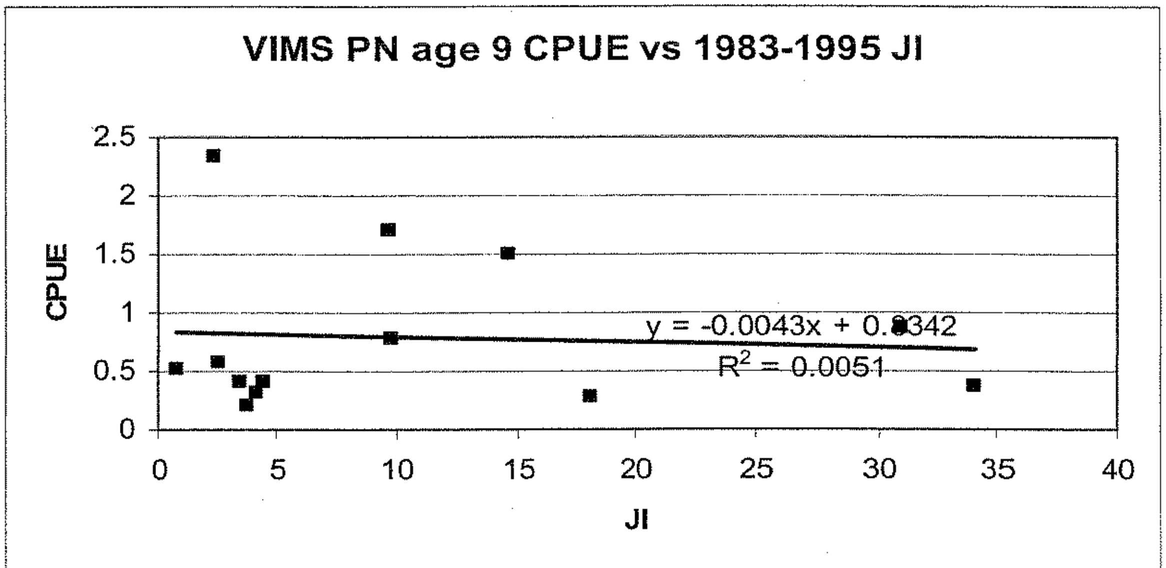


Figure 8. Correlation of the VIMS Rappahannock River juvenile indexes with their respective age-nine and age-ten CPUEs of striped bass from the pound net index.



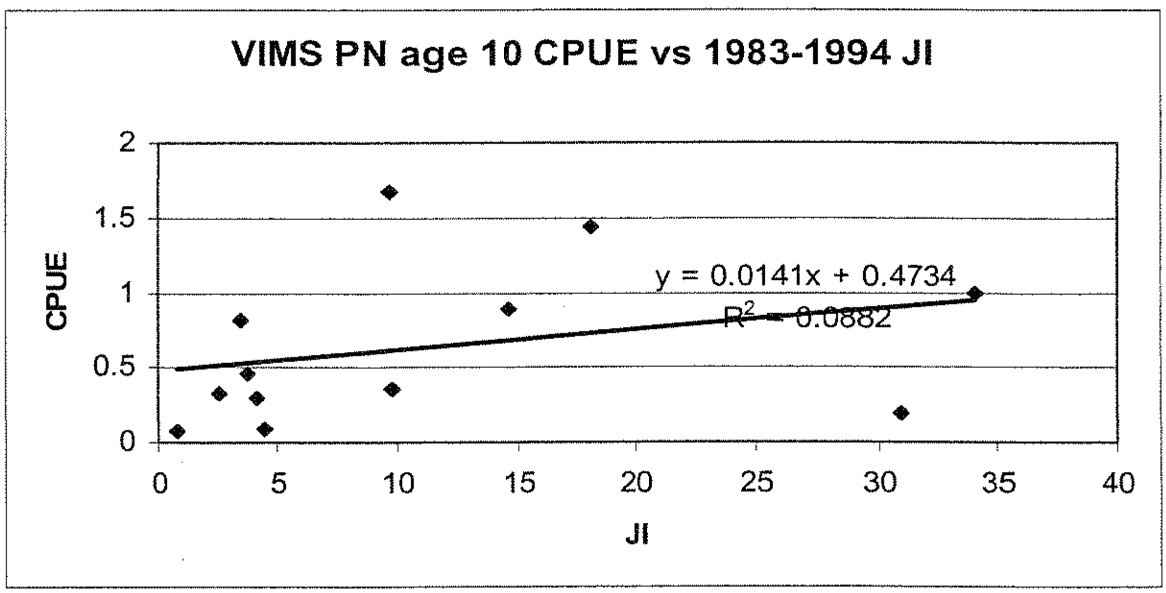
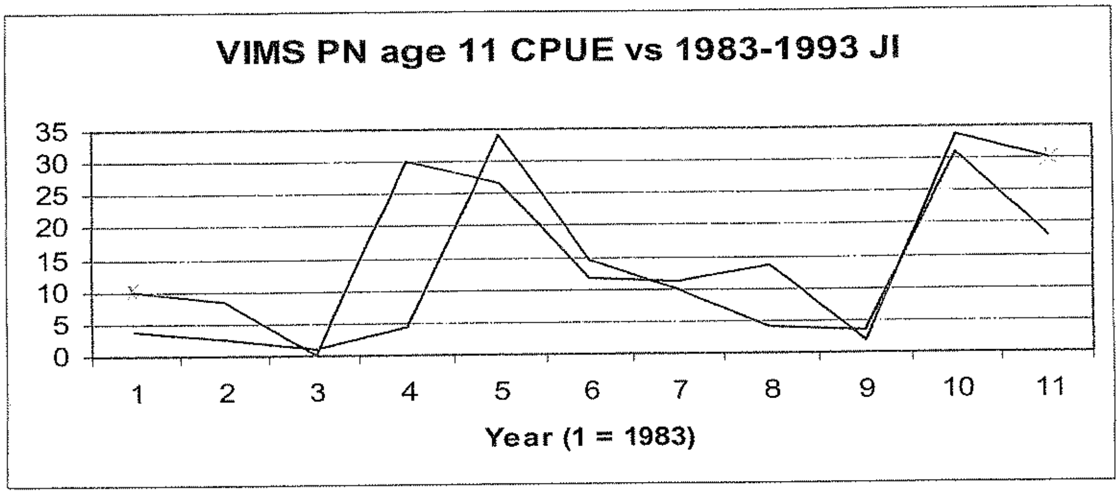


Figure 9. Comparison of the VIMS Rappahannock River juvenile indexes (red lines) with their respective age-eleven and age-twelve CPUEs (blue lines) of striped bass from the pound net index.



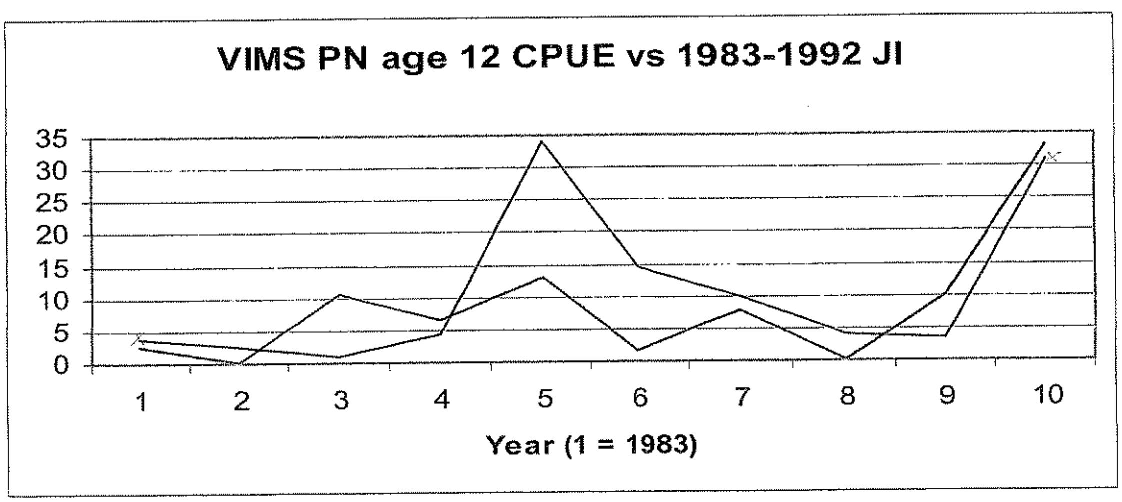
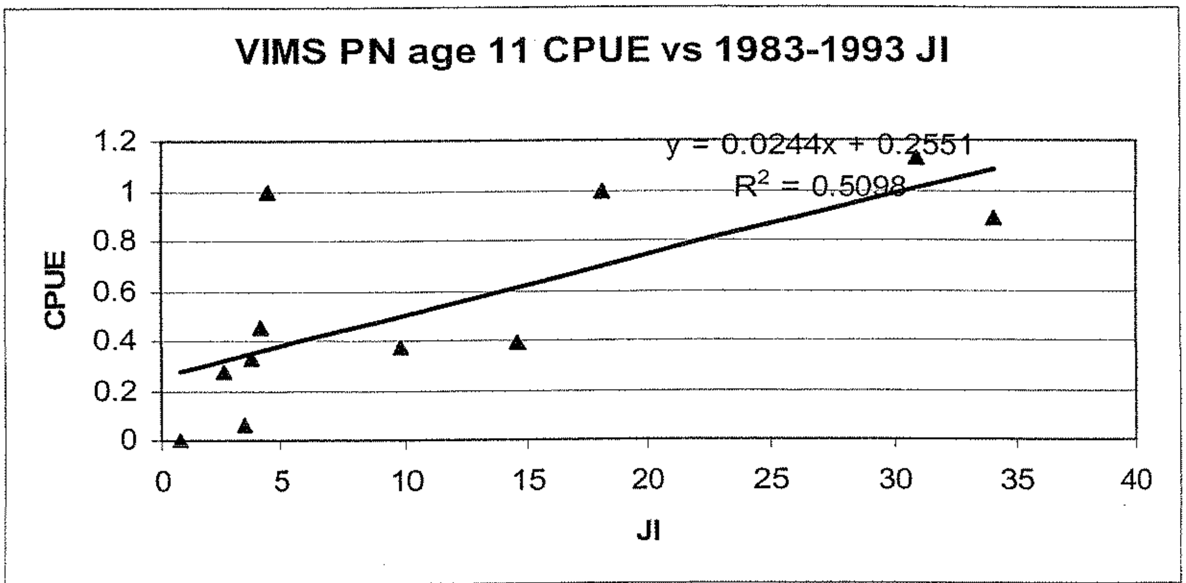


Figure 10. Correlation of the VIMS Rappahannock River juvenile indexes with their respective age-eleven and age-twelve CPUEs of striped bass from the pound net index.



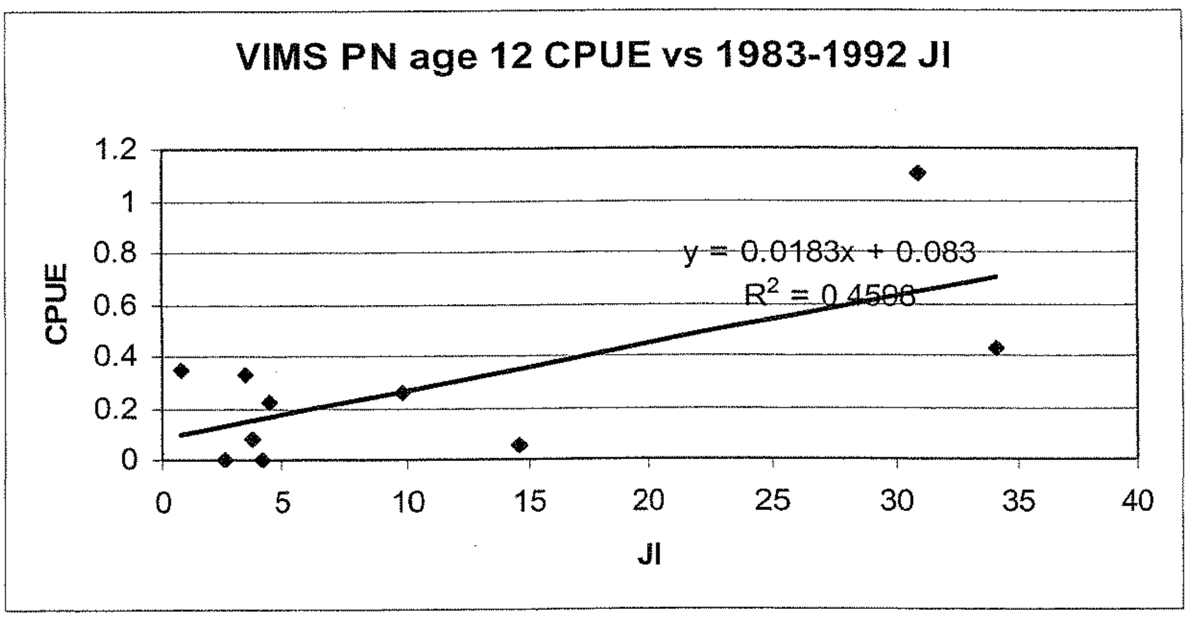
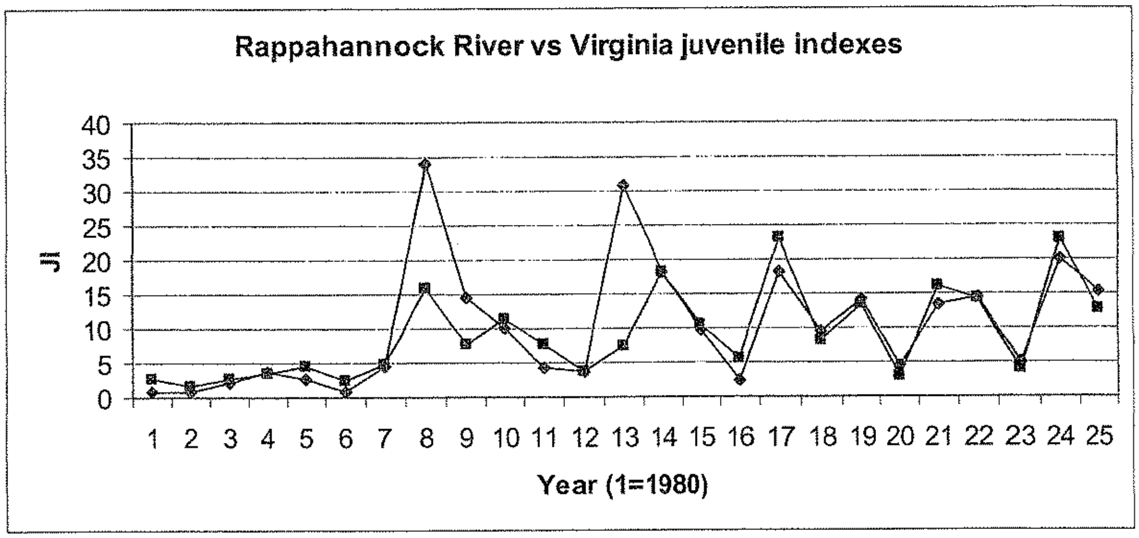


Figure 11. Comparison of the Rappahannock River juvenile index (red line) with the Virginia juvenile index (blue line) and their correlation, 1980-2004.



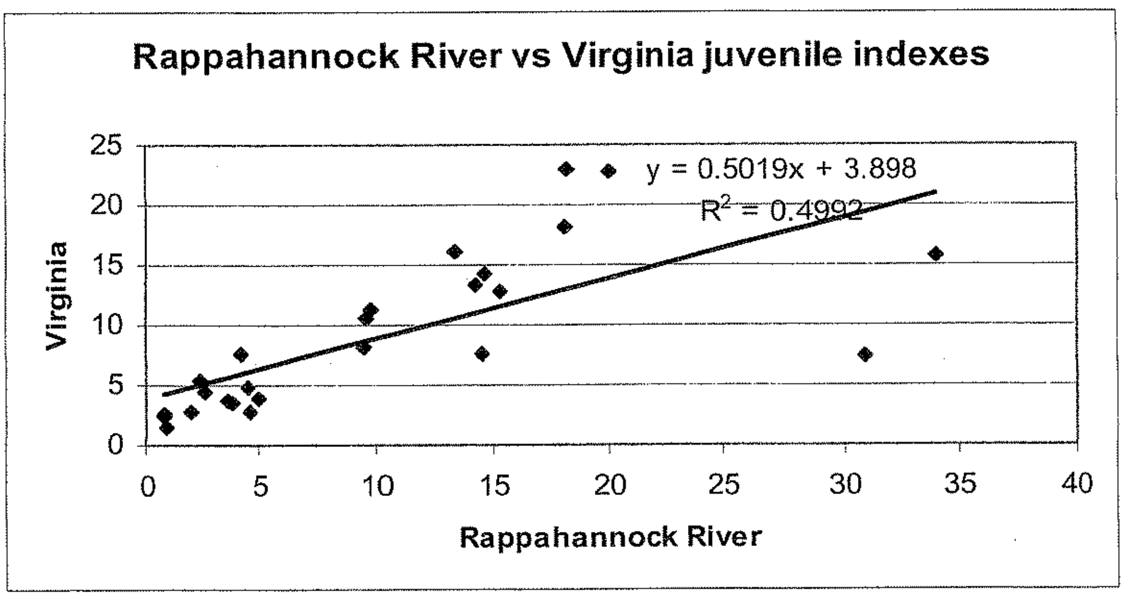
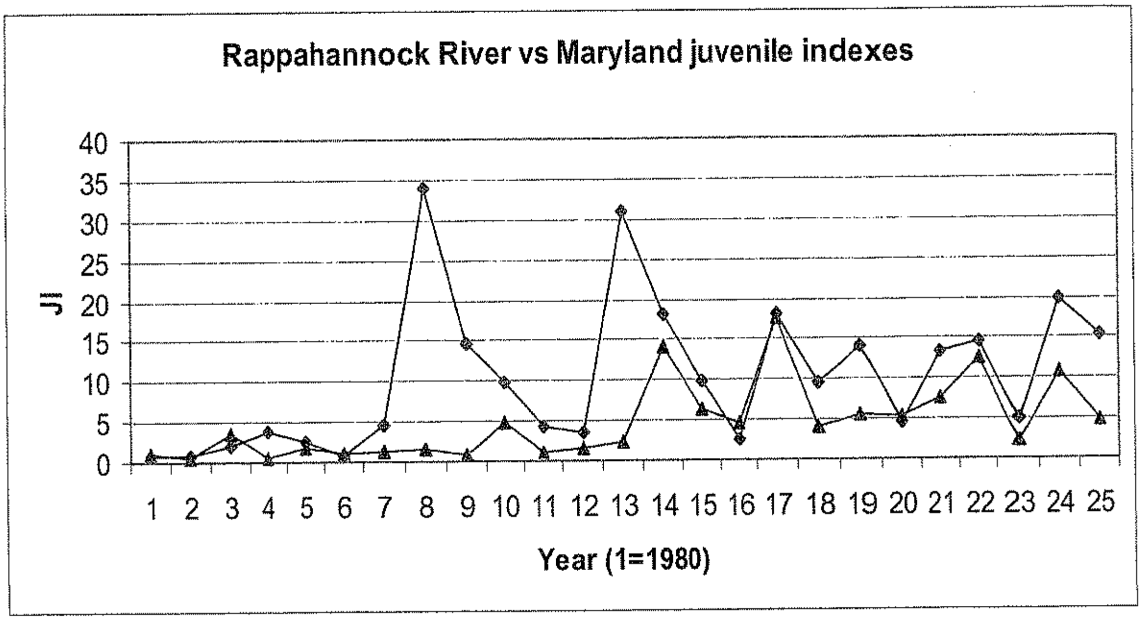
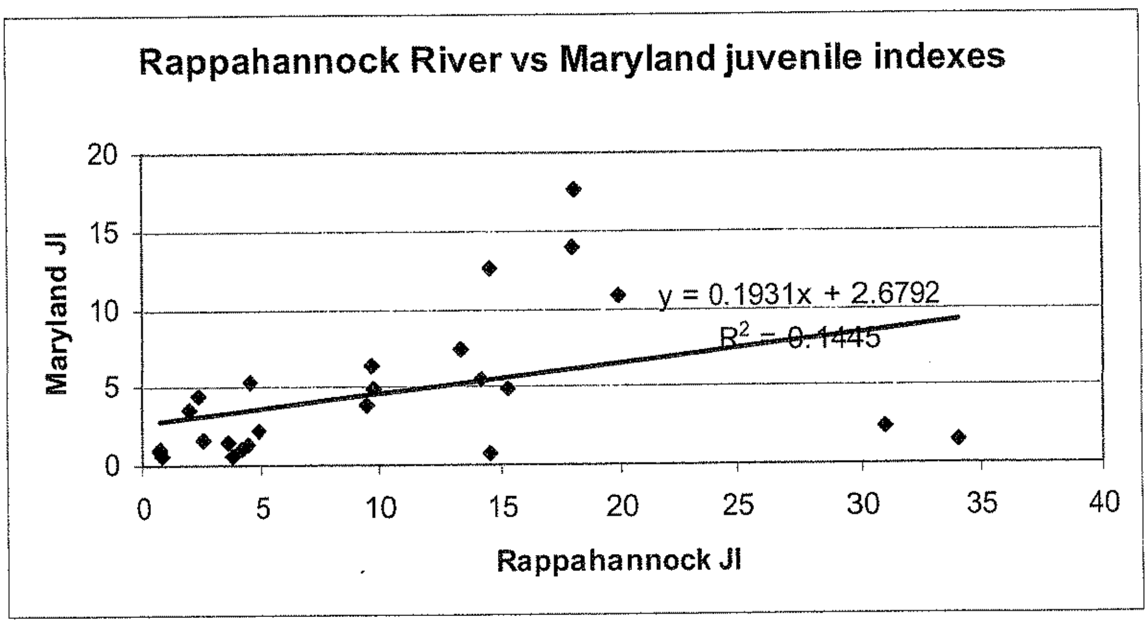


Figure 12. Comparison of the Rappahannock River juvenile index (red line) with the Maryland juvenile index (blue line) and their correlation, 1980-2004.





V. Comparison of the catches of the Rappahannock River pound nets, and the correlation of the Virginia Spawning Stock Biomass Indexes to the Maryland gill net indexes.

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Comparison of the catches of the Rappahannock River pound nets and the correlation of the Virginia Spawning Stock Biomass Indexes to the Maryland gill net indexes.

Introduction

From 1991 to 1996 there were only two pound nets (S441 and S473) available for obtaining striped bass monitoring samples from the spawning grounds in the Rappahannock River. Both nets were of identical size and configuration, but S441 (river mile 44) was located within a shallow bay (one to three meters in depth) while S473 (river mile 47) was located in a narrower section of the river with the head of the net in about four meters of depth and closely abutting the main channel (10+ meters deep). In 1997, a third net was added (S462, river mile 46), about ½ mile below S473, in a similar depth profile, and also closely abutting the channel. In 1999 the fourth net (S454, river mile 45) was added, located 1.5 miles below S462, and with a similar depth profile as nets S462 and S473. Throughout this period, the bay in which net S441 was located experienced continued shoaling and the fisherman discontinued its use after 2001. The use of the nets at river miles 45 and 46 was gradually incorporated into the monitoring sampling protocol after demonstrating that they provided samples that were similar in size, age and sex composition as the original two nets (at first they were used predominantly as a source for tagging striped bass).

Results

Comparison of the contributions of the four Rappahannock River pound nets to the Spawning Stock Biomass Index.

Catch rates. The mean catch rates (fish/day) of striped bass from the four pound nets are compared in Table 1. The catches of both male and female striped bass were generally highest from net S473 and lowest from net S441. Although nets S454 and S462 were sampled for monitoring much less frequently, they produced catch rates that were close to those of net S473. The standard errors to the mean catch rates from the four pound nets were also highest from net S473.

The mean biomass catch rates and their standard deviations (kg/day) of striped bass from the four pound nets showed similar patterns, with net S473 having the highest values and net S441 the lowest (Table 2). The temporal patterns in the mean values between nets S441 and S473 were not consistent. For example, the mean values increased between years from net S473 from 1997-1998, but fell from net S441. Likewise, the mean values increased at net S441 from 1995-1996, 1996-1997 and 1998-1999, but fell from net S473 (Figure 1).

Age. There was no consistent difference among the mean ages of the male or female striped bass captured from the four pound nets (Table 3). Each net showed an increase in the mean ages of both sexes in recent years (Figure 2). Thus, while there was variability in the catch rates among the pound nets, there was no indication of any age (therefore size) bias.

Correlation of catches. To maximize the data available to compare the catches among the four pound nets, the monitoring samples were correlated to the catches of the pound nets that provided striped bass for tagging that were fished on the same date (the monitoring sample was limited to striped bass >457 mm fork length, while the other nets included all tagged striped bass plus any untagged or recaptured striped bass >457 mm fork length). Since net S473 had the longest, most consistent sampling history, its catches were correlated to each of the other nets.

The catches of male striped bass from each of the other three nets had a positive correlation to the catches from net S473 (Figure 3). The values of R^2 ranged from 0.58-0.64. The narrow range of the R^2 values indicates that, over time, substituting these nets for each other would yield similar results if indexed for the lower catch rate from net S441.

The catches of female striped bass from each of the other three nets also had a positive correlation to the catches from net S473 (Figure 4). The values of R^2 ranged from 0.47-0.57. While these values are lower than those for the male striped bass, the narrow range indicates that substituting these nets for each other would yield similar results if indexed for the lower catch rate from net S441.

Correlation of the Rappahannock River Spawning Stock Biomass Index with the Maryland gill net spawning stock index.

The maximum value of the Rappahannock River female Spawning Stock Biomass Index (1991-2002) was 49.6 kg/day in 1997 and the minimum value was 9.3 kg/day in 1996 (Table 4). In contrast, the maximum value of the Maryland gill net female spawning stock biomass index was 547.7 kg/day in 1995 and the minimum value was 87.3 kg/day in 1994. There was a negative correlation between the Rappahannock River and Maryland Indexes (Figure 17). While the low values in the Rappahannock River index in 1996 and 2002 were probably the result of extreme environmental conditions within the river, there was little similarity in the temporal distribution between the two indexes.

Assessment of the Rappahannock River Spawning Stock Biomass Index as input in the VPA model.

Although there have been changes in the set of pound nets sampled over time, there is a notable correlation among the catches of the different nets, suggesting that the various nets are tracking the same population and the signal to noise ratio is high.

The lack of relationship between the Virginia and Maryland indexes suggest that the Virginia (actually Rappahannock River) and Maryland populations being different. Hence, both sets of data may be needed to get a representative picture of striped bass dynamics in Chesapeake Bay.

Table 1. Mean catch rates and standard deviations of male and female striped bass (fish/day) from the four pound nets sampled in the Rappahannock River, 30 March – 3 May, 1993-2004.

Year	CPUE (fish/day)							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	9.7			24.9	7			8.2
1994	3.5			16.9	1.9			10.8
1995	3.8			23.7	3.2			4.1
1996	8.4			14.9	0.9			6.1
1997	15.9			15.2	6.5			7.2
1998	6.6		10.3	22.7	2.6		5.4	5.5
1999	19.9	26		28.3	2.6	2.3		2.5
2000	31.9	14		45.9	0.7	4.3		2.4
2001	9.6	10.5		16.9	1.9	5.5		4
2002			5.7	2.9			2.9	1.5
2003		8.9	4	11.9		6.1	7.8	7.8
2004		22.1	29	25.6		7.8	9.1	9.1

Year	SD (fish/day)							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	5.6			19.9	4.3			1.6
1994	1.2			15.6	1.1			1.9
1995	4.1			24.8	1.3			3.7
1996	8.2			10	0.8			3.1
1997	12.8			4.9	10.9			4.5
1998	4.3		3.7	14.3	0.9		0.8	4.2
1999	9.2			21.4	3			1.8
2000	23.9			43	0.9			1.5
2001	9.4			13.6	0.9			2.8
2002			1.3	1.3			1.4	1.2
2003		6.3		8.4		2		4.8
2004		14.9		19.7		5.5		5.3

Note: net S454 was sampled once per year from1999 to 2001 and net S462 was sampled once in 2003 and 2004.

Table 2. Mean catch rates and standard deviations of male and female striped bass (kg/day) from the four pound nets sampled in the Rappahannock River, 30 March – 3 May, 1993-2004.

Year	CPUE (kg/ day)							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	21.9			52.9	35.9			38
1994	10.2			31.3	11.1			67.8
1995	5.1			27.7	19.1			24.5
1996	10.4			25.6	3.7			25.6
1997	21.6			20.4	49.4			62.5
1998	8.5		14.2	33.1	23.4		44.3	47.7
1999	16.3	45.1		30.2	25.7	18.6		23.5
2000	37.6	18.9		50.1	5.6	38.4		17.8
2001	12	15.1		29.1	15.6	9.8		32.4
2002			11.4	5.9			17.7	10
2003		22.3	12.2	26.8		55.4	17.5	63.5
2004		53.8	60.6	67.3		60.3	67.2	75

Year	SD (kg/day)							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	12.8			40.9	18			15.6
1994	5.1			22.1	6.9			19.9
1995	3.5			25.5	13			21.4
1996	9.6			19.3	3.5			14.8
1997	17.6			15.4	80.1			42.1
1998	4.6		3.6	18.9	9.6		7.4	31
1999	9.9			19.8	31			9.2
2000	29.3			42.7	6.1			11.2
2001	11.6			17.8	5.5			24.9
2002			1.2	4.1			13.3	10
2003		15.3		16.7		25.9		37
2004		34.7		31.6		45.5		43.4

Note: net S454 was sampled once per year from1999 to 2001 and net S462 was sampled once in 2003 and 2004.

Table 3. Mean ages of male and female striped bass from the four pound nets in the Rappahannock River, 30 March – 3 May, 1993-2004.

Year	Mean Age							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	4.7			4.5	7			6.6
1994	5.2			4.4	7.1			7.1
1995	3.2			3.2	6.2			4.7
1996	3.7			4	6.5			6.1
1997	3.8			3.9	8.7			9.2
1998	3.8		3.8	3.7	9.6		9	9
1999	3.7	4.4		3.6	10.4	8.7		9.9
2000	3.8	4		3.7	8.7	9.8		8.6
2001	4	4.3		4.4	8.8	9.5		9.1
2002			4.5	4.6			7.6	7.8
2003		5.2	5.8	5.1		9.7	9.2	9.3
2004		5.2	4.6	5.4		9.2	9.5	9.7

Note: net S454 was sampled once per year from 1999 to 2001 and net S462 was sampled once in 2003 and 2004.

Table 4. Values of the Rappahannock River pound net and the Maryland gill net female Spawning Stock Biomass Indexes (kg/day), 1991-2002.

	female SSBI	
Year	Virginia	Maryland
1991	21.5	109.4
1992	19.4	275
1993	37.5	278.5
1994	30.9	87.3
1995	19.8	547.7
1996	9.3	347.9
1997	49.6	256.9
1998	36.4	157.4
1999	19.8	161.4
2000	14.6	169.9
2001	27.6	490.2
2002	11.4	266.4

Figure 1. Comparison of the mean annual catch rates between the pound nets in the Rappahannock River, 30 March – 3 May, 1993-2004.

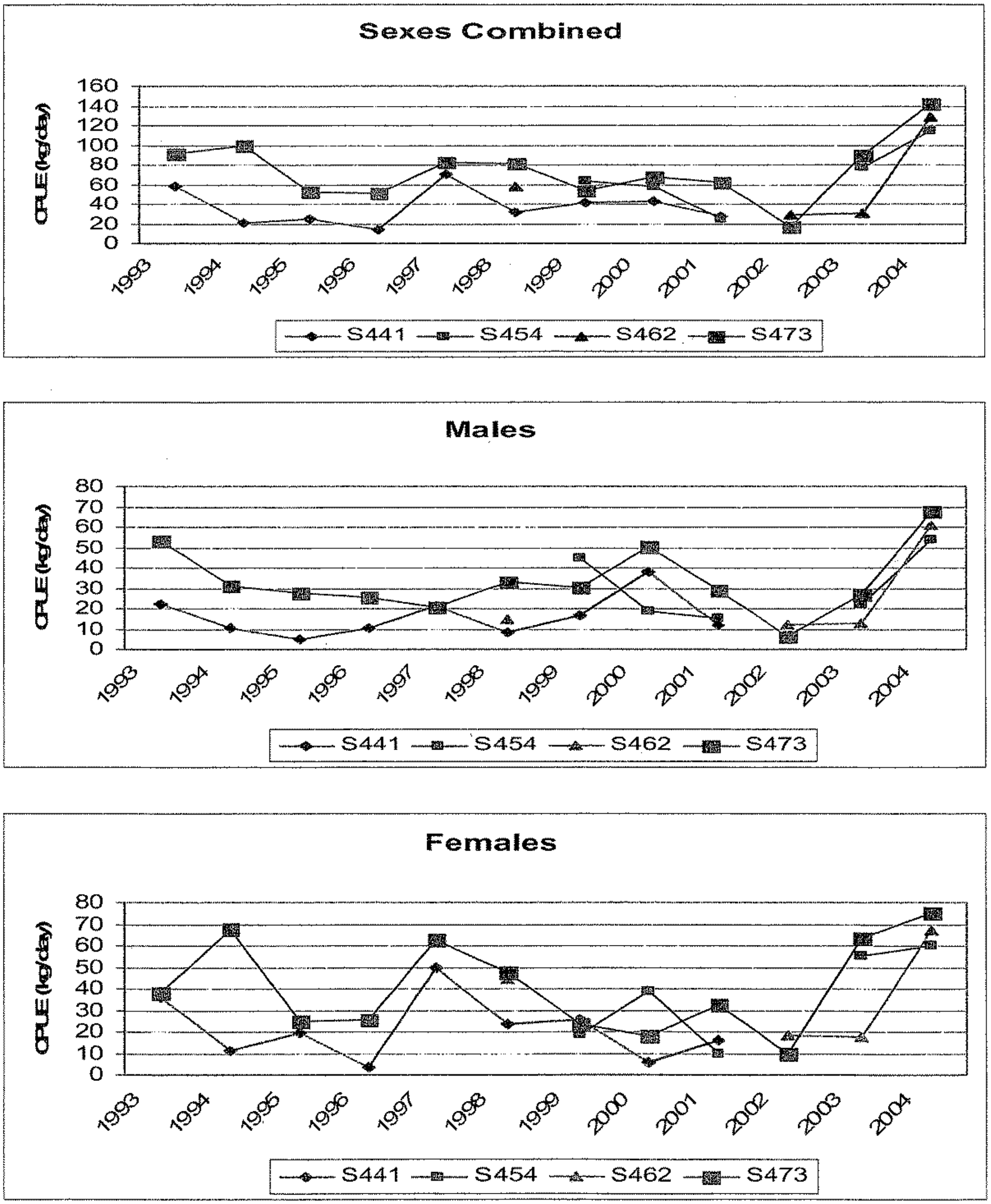
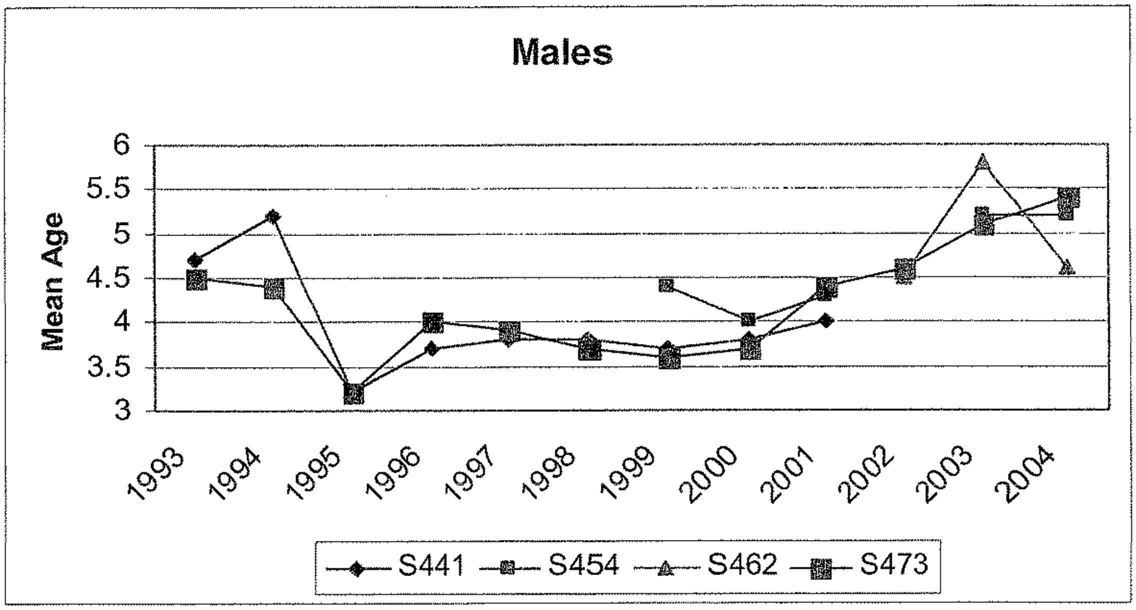


Figure 2. Comparison of the annual mean ages of male and female striped bass from the pound nets in the Rappahannock River, 30 March – 3 May, 1993-2004.



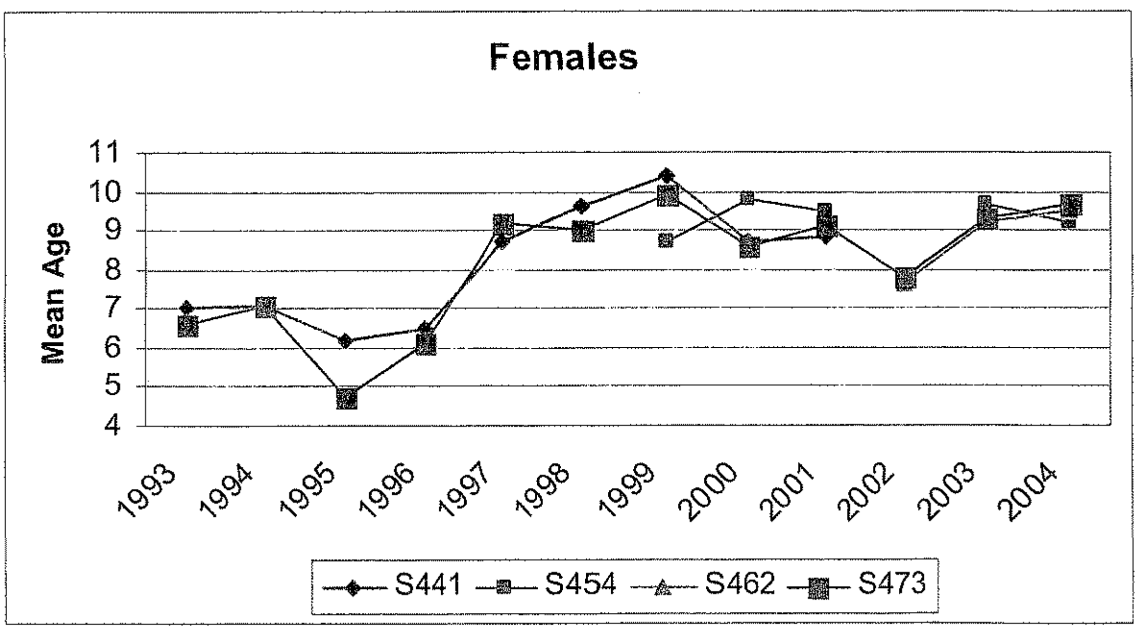
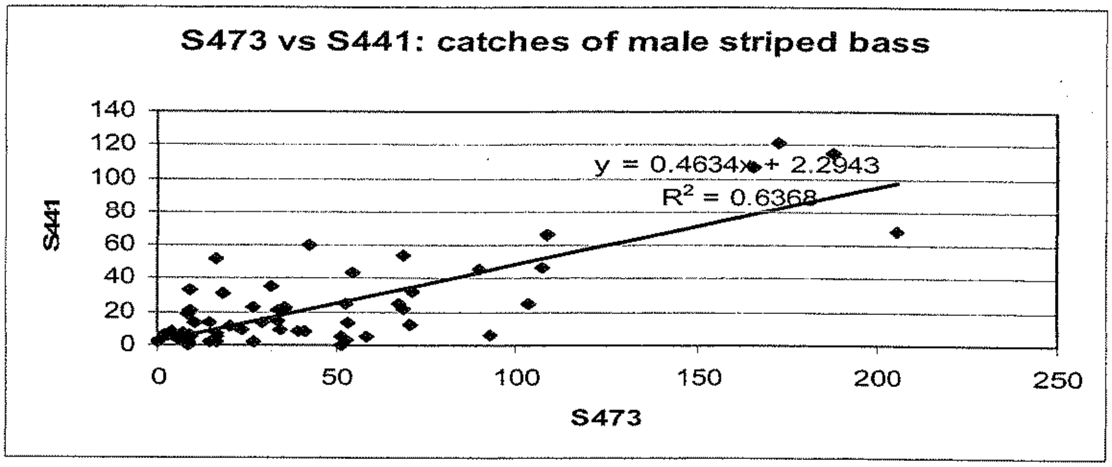
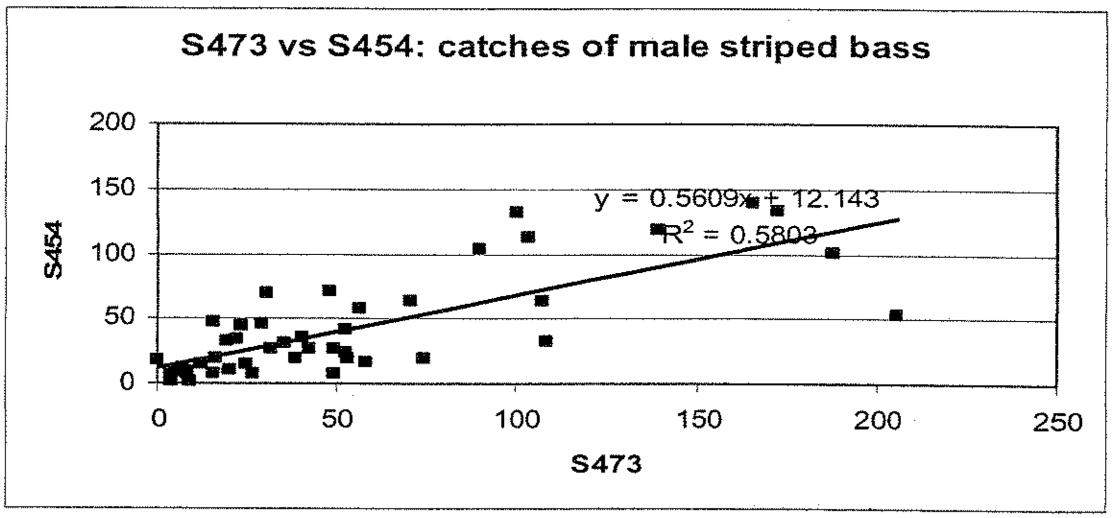


Figure 3. Correlations of the catches of male striped bass from net S473 with those from nets S441 (1993-2001), S454 (1998-2004) and S462 (1997-2004).





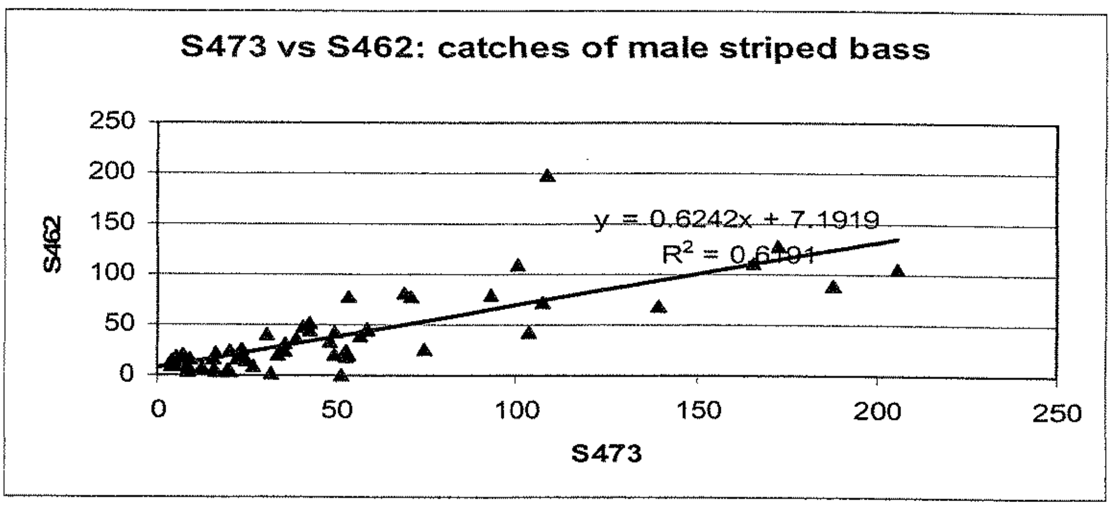
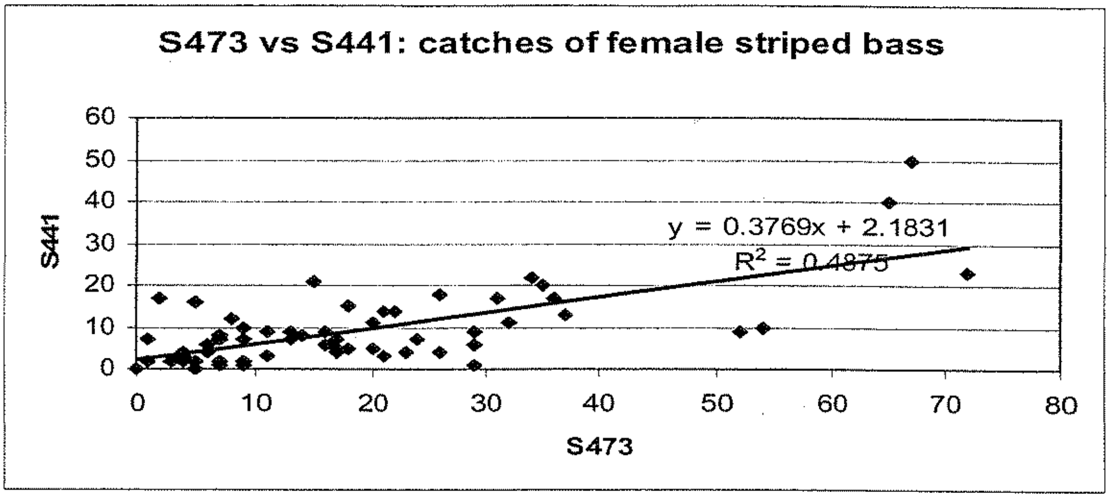
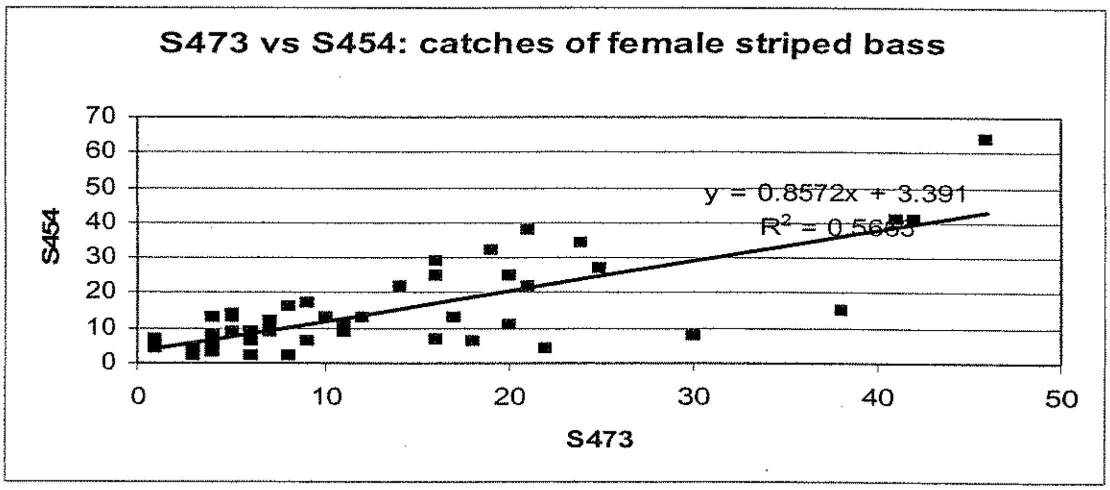


Figure 4. Correlations of the catches of female striped bass from net S473 with those from nets S441 (1993-2001), S454 (1998-2004) and S462 (1997-2004).





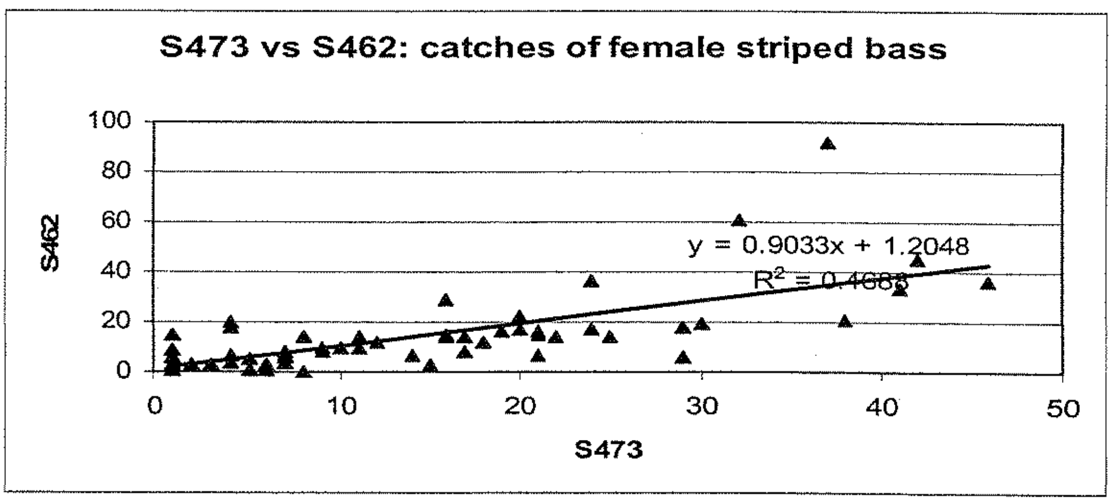
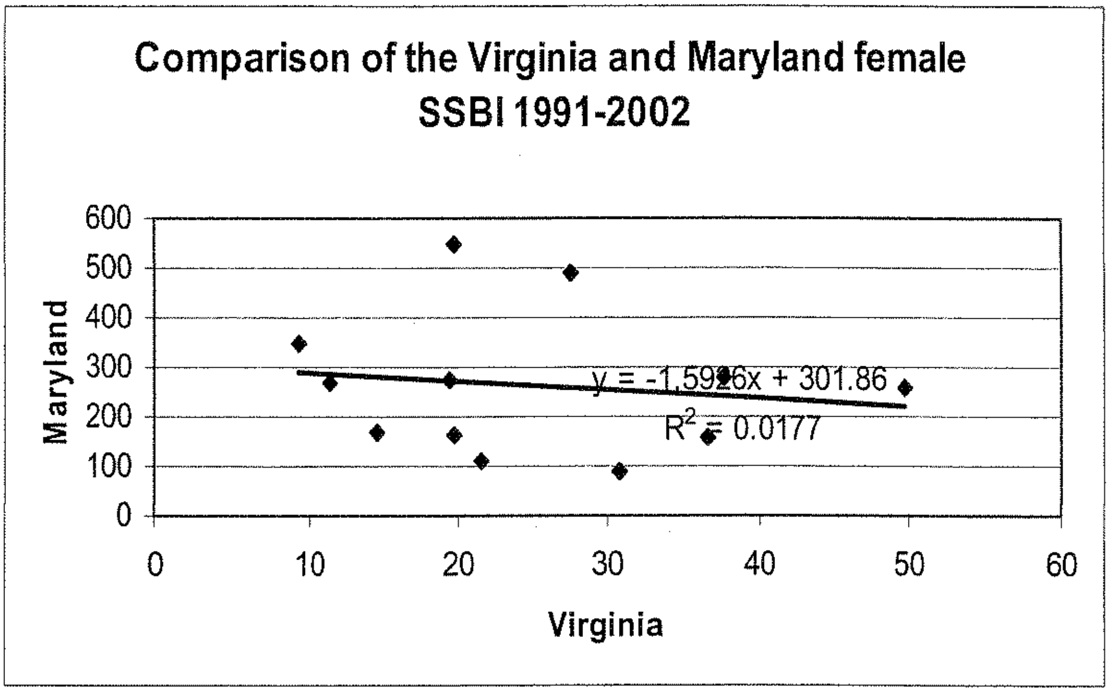


Figure 5. Correlation of the Rappahannock River pound net Spawning Stock Biomass Indexes with the Maryland gill net spawning stock indexes, 1991-2002.



VI. Evaluation of the 2000-2004 striped bass by-catch from the American shad staked gill net stock assessment survey in the James and Rappahannock rivers as an alternative index of abundance.

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Acknowledgements

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Introduction

Historically, American shad (*Alosa sapidissima*) supported large commercial fisheries in Chesapeake Bay and along the U.S. and Canadian east coasts. However, coast-wide landings declined from 50 million pounds in 1900 to 1.5 million pounds in 1993. Commencing in 1994, a total moratorium on shad fishing was established for the Chesapeake Bay and its tributaries in Virginia.

In 1998, the *Alosa* Stock Assessment Task Force was established at the Virginia Institute of Marine Science (VIMS). Staked gill nets were established in the James, York and Rappahannock rivers to monitor relative abundance. Staked gill nets were the predominant commercial gear utilized in the shad fishery in these rivers, and the new program allowed comparison with historic catch rate data recorded in fishers' logbooks. In addition to American shad, these nets also catch significant numbers of striped bass. The potential for utilizing these data as a useful index of striped bass abundance is investigated in this report.

Material and Methods

When the shad moratorium was imposed in 1994, commercial fishermen who held permits for existing stands of staked gill nets (SGN) retained proprietary rights to those sites for all future use. VIMS has historic catch data from staked gill nets in James, York and Rappahannock rivers. One cooperating fishermen on each river was contracted to establish a monitoring staked gill net similar to what was used to provide the previous catch data.

The staked gill net on the James River is located at river mile 10, near the James River Bridge. This net consisted of 30, 30-foot panels (between stakes) of 4.88 inch stretched mesh monofilament nylon netting. The staked gill net on the Rappahannock River iss located at river mile 37, near the Route 360 Bridge at Tappahannock. This net consisted of 19, 48-foot panels of 5.0 inch stretched mesh monofilament nylon netting. The two nets reflect river-specific differences in staked gill nets fished in the James and Rappahannock rivers. Each net is fished twice-weekly (usually on Sunday and Monday). The set time is 24 hours.

The striped bass by-catch was also collected and brought to VIMS for work-up. In periods of extreme abundance, a sub-sample of randomly chosen panels was segregated for work-up, with a target of approximately 50 striped bass per week. A total count of the striped bass caught in the net was made to allow extrapolation of the work-up data. The work-up data consisted of total length (in mm), weight (g) and sex. A scale sample was taken for subsequent ageing from between the two dorsal fins and above the lateral line. A complete description of the collection methods can be found in the American shad stock assessment annual report (Olney 2004). The striped bass ageing methodology was described in section I of this report.

The multi-mesh experimental anchor gill nets are located at river mile 62 on the James River and at river mile 48 on the Rappahannock River. Two 300-foot nets consisting of 10 30-foot sections on differentially sized meshes (3.0, 3.75, 4.5, 5.25, 6.0, 6.5, 7.0, 8.0, 9.0 and 10.0 inches stretched nylon monofilament) are fished twice-weekly (usually on Monday and Thursday) from each river. The set time is 24 hours. All striped bass are brought back to VIMS for biological work-up. The complete methodology is described in Section I of this report.

In order to compare catch rates from the *Alosa* project staked gillnets and the striped bass monitoring program experimental multimesh gillnets, we restrict attention to the catches occurring between 30 March and 3 May of each year. Five years of data are currently available (2000–2004). There are two comparisons that can be made: size-specific catch rates and age-specific catch rates. In this report, we restrict attention to the size-specific catch rates. This comparison is of interest because it does not depend on the reliability of age determinations. In the future, we intend to also compare age-specific catch rates.

It should be noted that the staked gillnets are composed of a single mesh size which means they are selective for a much narrower size range than the experimental multi-mesh gillnets. Catch rates outside the selection range are likely to be low and highly variable because the nets are not efficient for catching very large and very small fish. Consequently, we might anticipate that the catches in the staked gillnets correlate well with the catches in the multi-mesh gillnets only over a limited size range.

Results

In the James and the Rappahannock rivers, catches were highest for striped bass between 18 and 24 inches total length (Figures 1a,b). This range of sizes contributed 80.4% (Rappahannock River) to 83.7% (James River) of the total staked gill net catches and 54.6% (Rappahannock River) and 71.0% of the total experimental gill nets catches. All further analysis was based on the striped bass from this range of total lengths.

Plots of catch per net in the staked gillnets versus catch per net in the experimental multi-mesh nets are shown in Figures 2 (a and b) for the James River and in Figures 3 (a and b) for the Rappahannock River. For the James River, slopes of linear regressions are positive with correlations (R^2) of 0.60, 0.72 and 0.26 for fish of 18, 19, and 20 inches total length, respectively. Above 20 inches, the results were less good: slope is negative for 21 inch fish, positive for 22 inches, negative for 23 inches, and slightly positive for 24 inches.

For the Rappahannock River, the results did not support the idea that the two sampling programs were tracking the same population. Only for fish of length 23 inches was the slope more than slightly positive, with an R^2 of 0.32. For the other sizes the slopes were either negative or just lightly positive.

Discussion

It is encouraging that the two sampling programs in the James River provide correlated catch rates for a series of adjacent size classes. This supports the idea that the two programs are tracking the same population – but only over a narrow size range. Components of the striped bass population appear to segregate spatially, at least at certain times, and these components may exhibit complicated movement patterns in response to environmental factors such as water temperature and in response to stage in the reproductive cycle. The two monitoring programs in the James River take place in different locations (staked gill net at river mile 10, experimental gill net at river mile 62). It appears that when striped bass greater than 21.0 inches are in one place they are not in the other, resulting in a negative correlation.

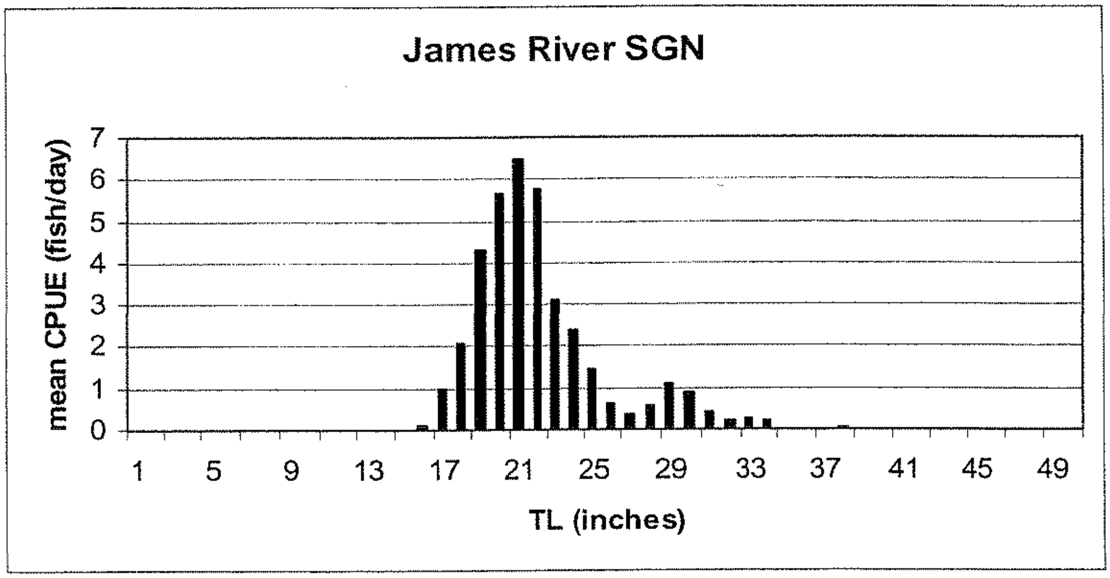
The results for the Rappahannock River are problematic. The two programs appear to be monitoring different populations. This raises the question of which program, if either, is providing a valid index of the stock-wide (but size-specific) abundance. The results suggest that further work is needed to develop and evaluate indices for the Rappahannock River.

It is noteworthy that these comparisons are based on just five data points. A progressively more reliable evaluation will develop as increased data points accrue.

Literature cited

Olney, J.E. 2004. Monitoring Relative Abundance of American Shad in Virginia's Rivers. Annual Report. 83p.

Figure 1a. Comparison of the seasonal mean catch rate (fish/day) frequencies, in inches total length, of the striped bass captured in the staked gill net and multi-mesh experimental gill nets in the James River, 30 March – 3 May, 2000-2004.



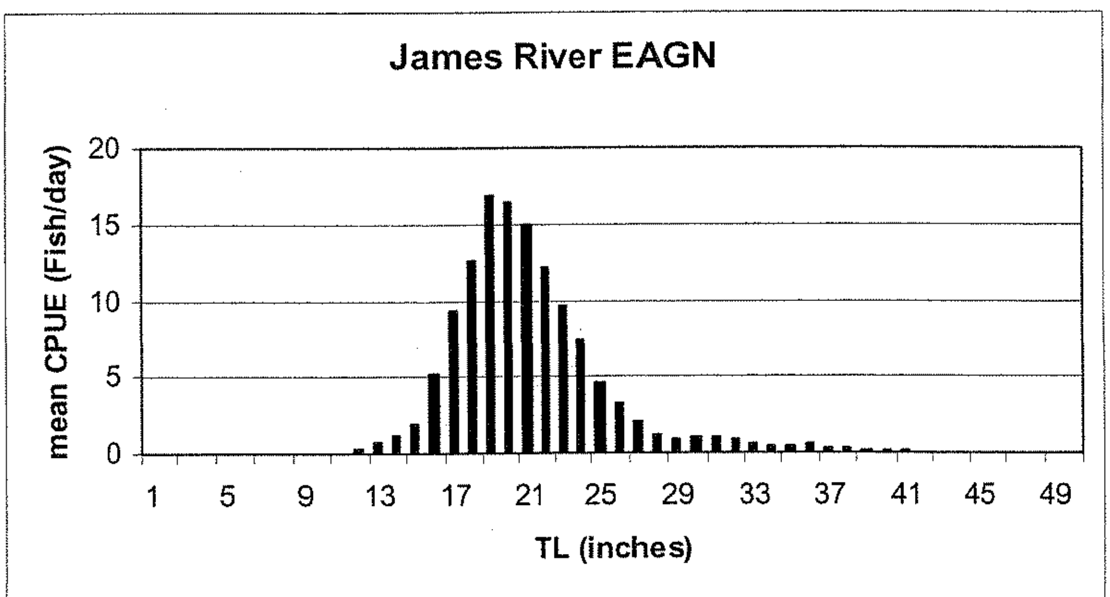
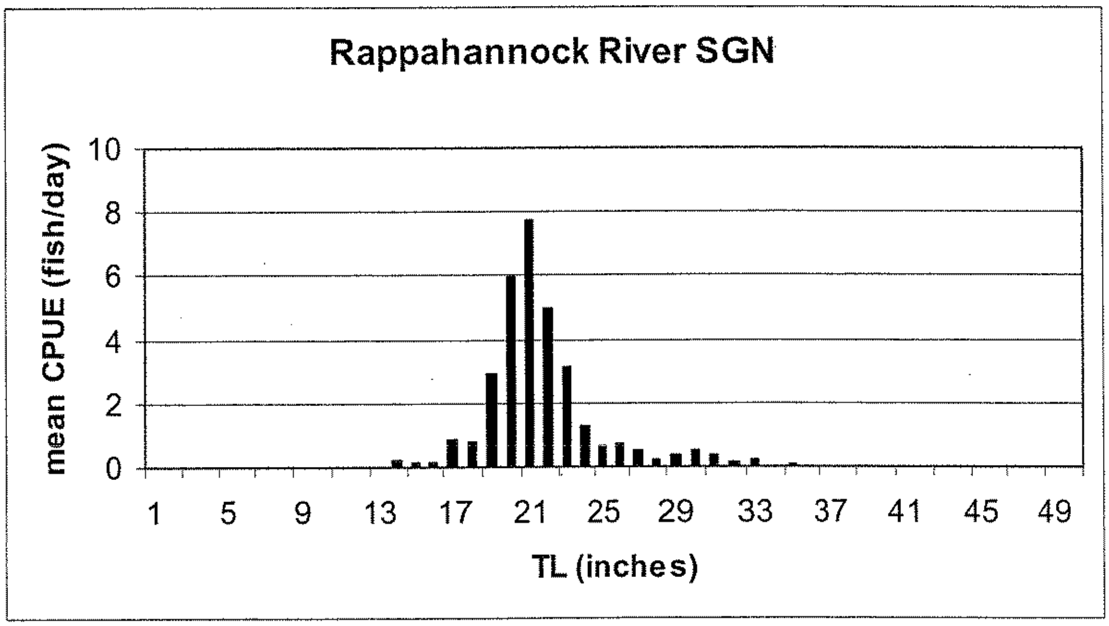


Figure 1b. Comparison of the seasonal mean catch rate (fish/day) frequencies, in inches total length, of the striped bass captured in the staked gill net and the multi-mesh experimental gill nets in the Rappahannock River, 30 March – 3 May, 2000-2004.



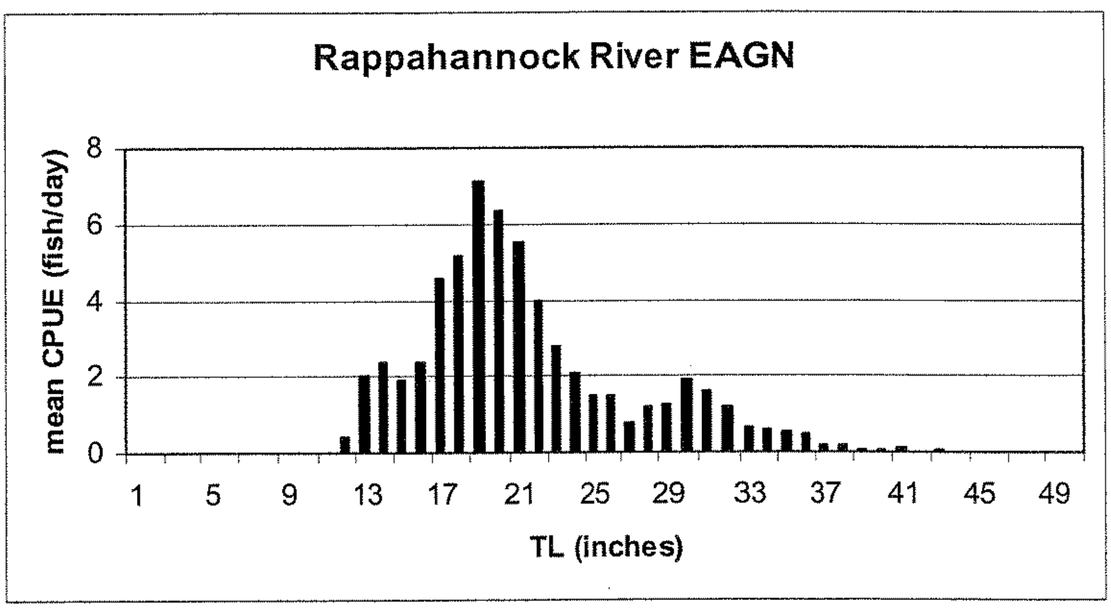


Figure 2a. Correlation of the seasonal mean CPUE (fish/day) of 18-20 inch total length striped bass captured in the multi-mesh, experimental gill nets and staked gill nets in the James River, 30 March – 3 May, 2000-2004.

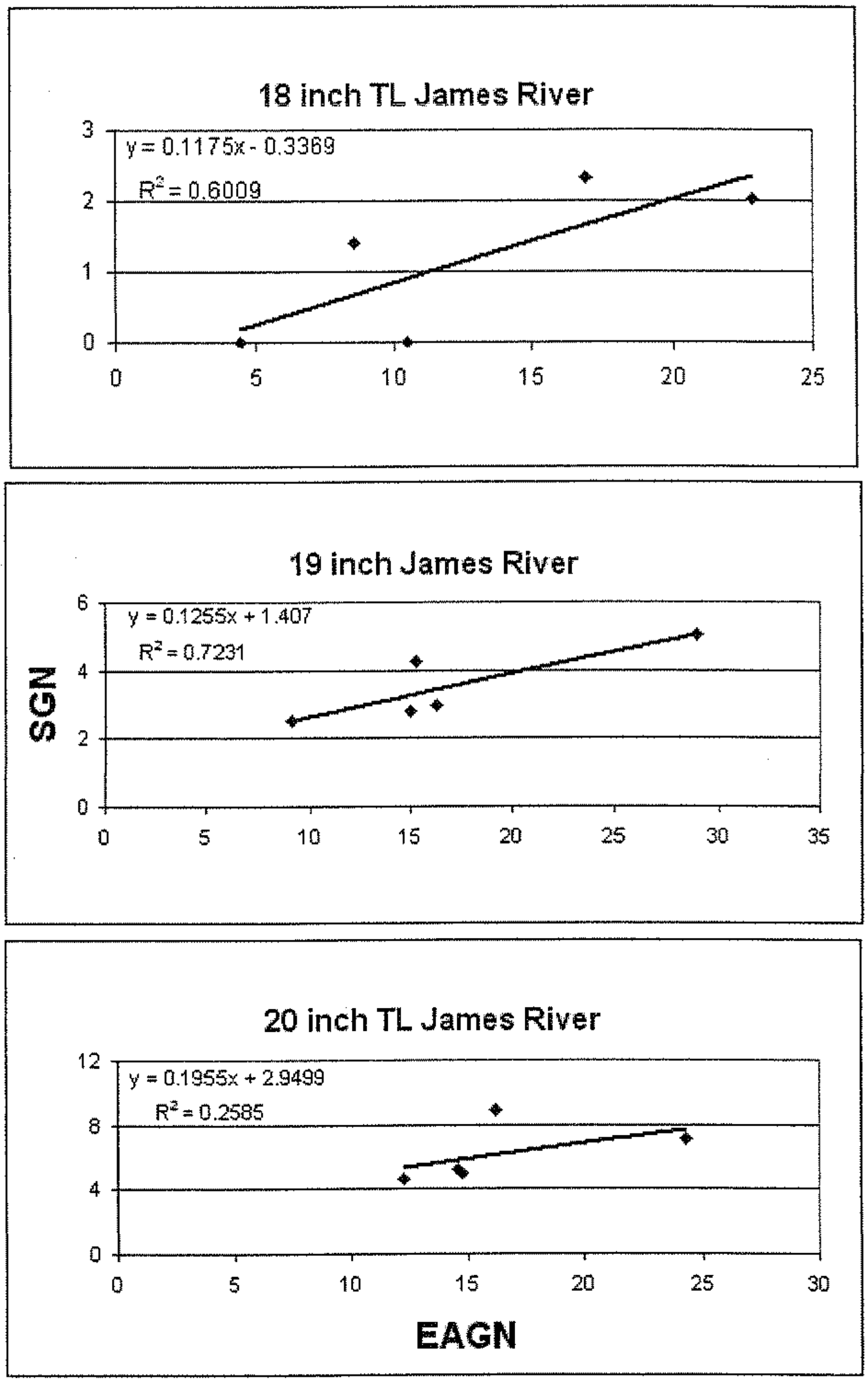


Figure 2b. Correlation of the seasonal mean CPUE (fish/day) of 21-24 inch total length striped bass captured in the multi-mesh, experimental gill nets and staked gill nets in the James River, 30 March – 3 May, 2000-2004.

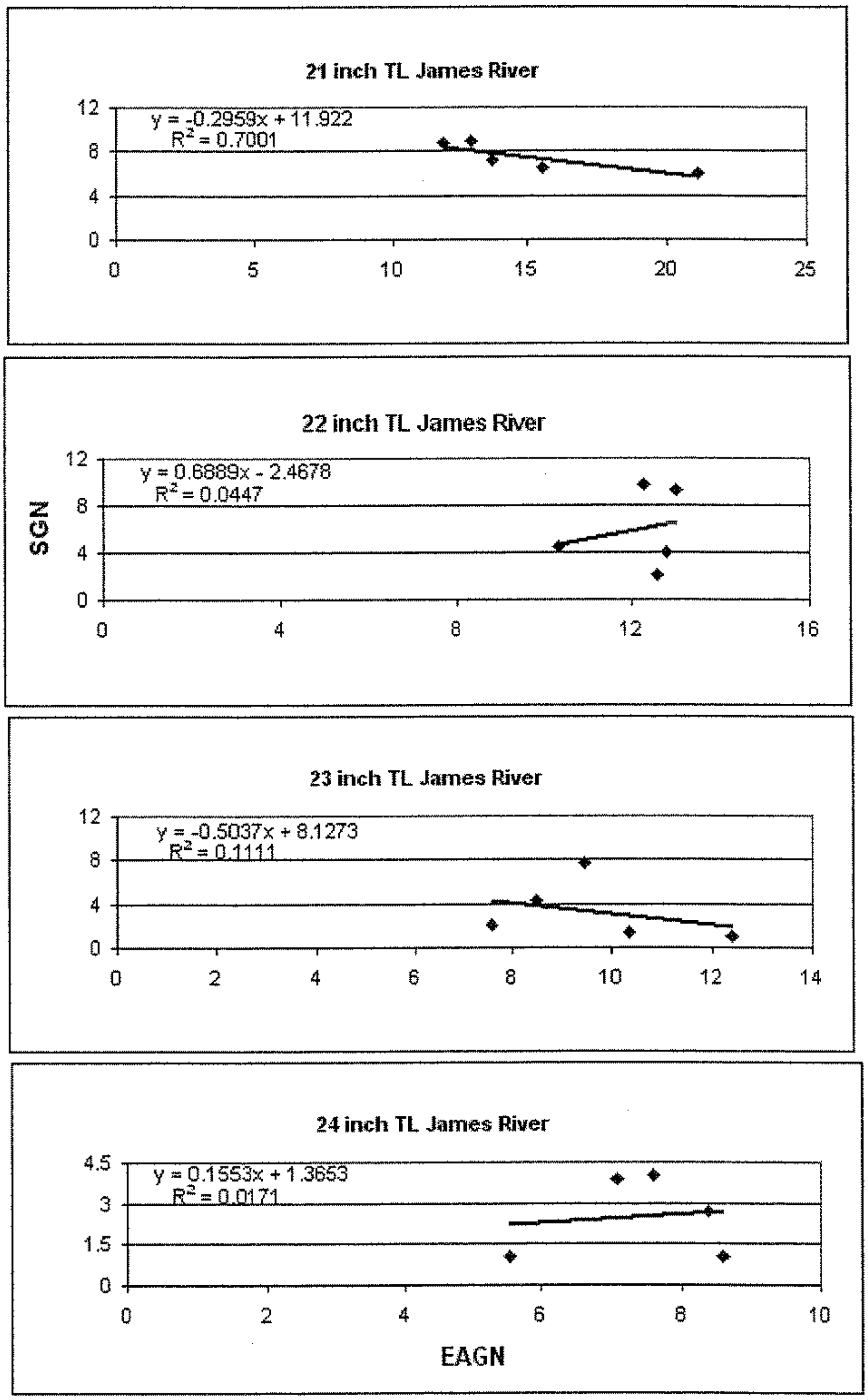


Figure 3a. Correlation of the seasonal mean CPUE (fish/day) of 18-20 inch total length striped bass captured in the multi-mesh, experimental gill nets and staked gill nets in the Rappahannock River, 30 March – 3 May, 2000-2004.

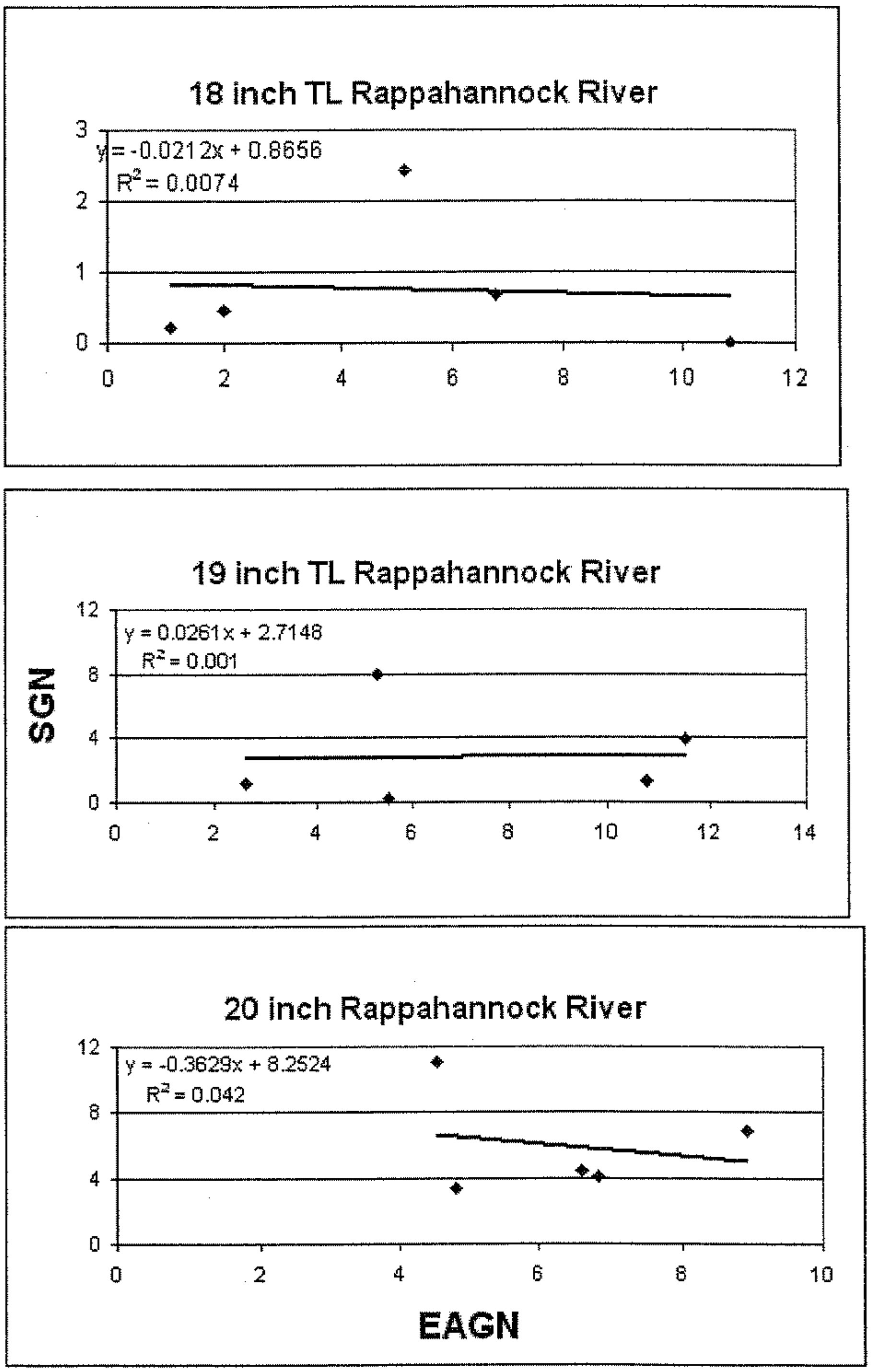


Figure 3b. Correlation of the seasonal mean CPUE (fish/day) of 18-24 inch total length striped bass captured in the multi-mesh, experimental gill nets and staked gill nets in the Rappahannock River, 30 March – 3 May, 2000-2004.